COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

L. 6, No. 2 | AUGUST, 1934 | 25c a copy

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New boiler plant of the Chrysler Corporation at Newcastle, Indiana, containing two 140,000 lb steam-generating units

New Steam-Generating Unit Installed at Picway

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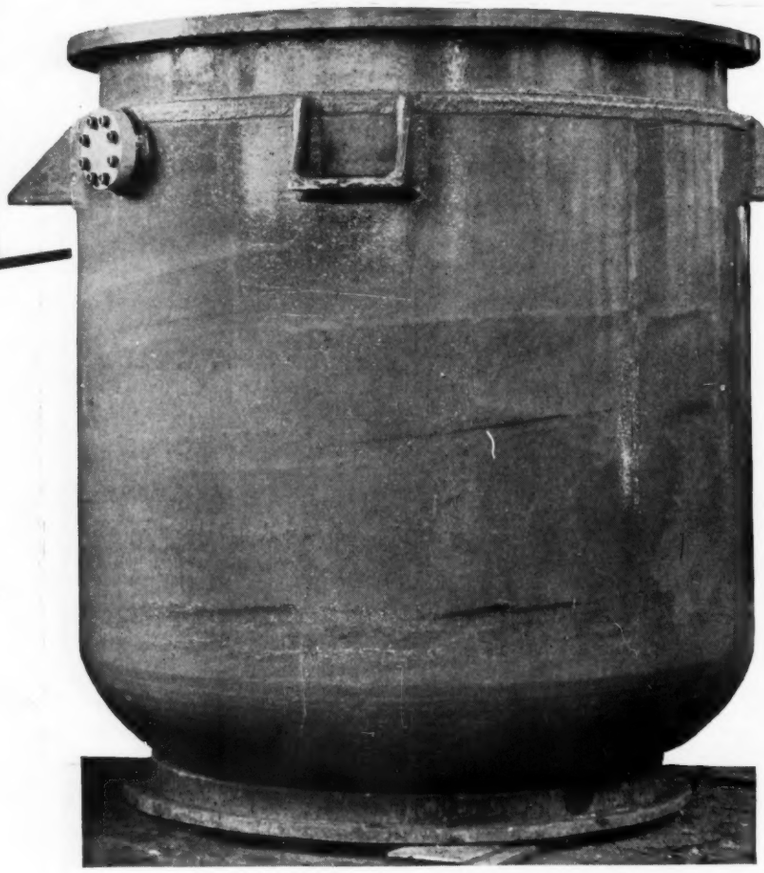

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DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SIX NUMBER TWO

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NUGGETS

Replacement of 5 old boilers by 1 new high pressure boiler prevents loss shown

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COMBUSTION

EDITORIAL

Good or Indifferent Welding

Although the A.S.M.E. Boiler Code prescribes Class I welding, with all its safeguards, for power boilers, there are many unfired pressure vessels the character of whose service makes Class I welding highly desirable.

During the past legislative year several bills, aimed at safeguarding welding through fixing qualifications for welders, were introduced but failed of enactment. Inasmuch as welding has now become so widely employed in all forms of fabrication and repair work, into many of which the element of safety does not enter, it was to be expected that legislation governing the qualifications of welders would meet resistance from many quarters. After all, more can be accomplished by education and the influence of engineering societies than through legislation.

Nevertheless, there are numerous shops, lacking facilities for Class I welding, that are turning out work on unfired pressure vessels without any positive check as to its character. Price considerations under the NRA Codes have intensified this situation. Under these conditions, it remains for the purchaser to decide whether the experience and facilities of Class I welding shops, as an assurance of quality work, are worth the slightly higher cost. It may take a few failures in service to convince some that they have been "penny wise and pound foolish," but the good judgment of the experienced engineer can usually be relied upon to play safe.

Prime Movers Committee

It is gratifying that the Prime Movers Committee, whose outstanding work in advancing station operating practice and contributions to engineering knowledge were so widely recognized, has been revived under the Edison Electric Institute. When the latter organization superseded the N.E.L.A. over a year ago, the Prime Movers Committee, together with several other specialized technical committees, was abolished and the technical activities were grouped under one general committee, namely, the Power Generation Committee.

There were many who felt, however, that both the scope and the personnel of the new committee precluded consideration of many operating problems in detail and failed to provide a means for the discussion of these problems by the men who were intimately concerned with them. Moreover, the sub-committee reports which were printed and issued periodically under the old set-up provided a means for disseminating the information among central station men outside the limited group that was privileged to sit in at the committee meetings. Under the present arrangement the former procedure has been restored and should meet with approval.

Power by Commission Rule

The English alphabet affords over fifteen thousand permutations of three letters; hence those who are beginning to complain of mental limitations in grasping the numerous designations of governmental agencies can take heart that the possibilities are by no means exhausted. Power-minded individuals have had only a few to remember such as the TVA (Tennessee Valley Authority), PWA (Public Works Administration), MVC (Mississippi Valley Committee), FTC (Federal Trade Commission) and FPC (Federal Power Commission)—all actively delving into power problems. Now comes the FSEC (Federal Stock Exchange Commission) which will look into the financial aspects of power companies and the more recently created NPPC (National Power Policy Committee) which is charged with the duty of developing a national power policy based on the surveys, investigations and ramifications of the above-named bodies, as well as those of the Reclamation Service, the Forestry Service and the Army Engineers.

Since the Government has now seen fit to employ four-letter designations as applied to power matters, there is truly cause for alarm as this raises the ante to over three hundred and fifty-eight thousand possible permutations.

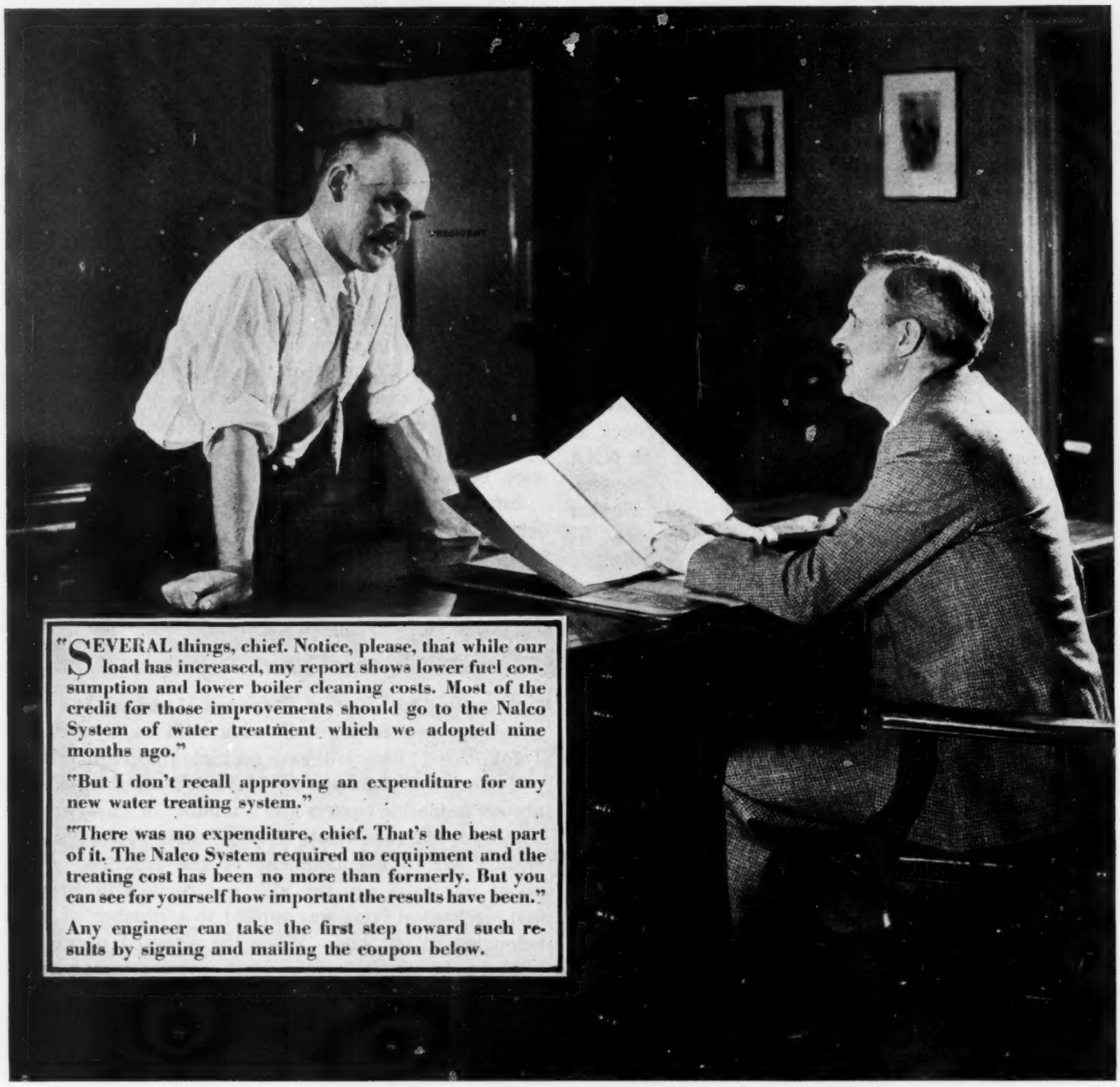
Marine Stokers

According to *The Fuel Economist* (London), the three sea-going train ferries now being built to ply between Dunkirk and Dover will have multiple-retort stokers.

Twenty-five years ago considerable interest was shown abroad in marine stokers and a number of ships were so equipped, but considerations other than efficiency in operation led to abandonment of the practice. Again about ten years ago the idea was revived in England and mechanical firing was applied to a number of ships belonging to one line. While the reported results appeared to be satisfactory, no great enthusiasm was shown in shipping circles.

In this country two stoker-fired vessels have been operating on the Great Lakes for several years; but the practice, although not lacking advocates, has made little headway. The principal obstacle appears to lie in getting the coal to the hoppers without undue manual labor. In a new vessel, especially constructed for such equipment, the problem would be much simpler than in a vessel converted to such firing. But it appears to be the usual procedure to try out new developments on existing vessels. Moreover, fuel oil is plentiful in this country and, until recently, was obtainable at relatively low prices. In England, however, the coal industry is seeking further markets for its product and fuel oil must be imported.

"What did you do to cut steam costs so much?"



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New Steam-Generating Unit Installed at Picway

By G. T. SHOEMAKER, Vice President
The United Light and Power Engineering & Construction Co.

The unit replaces one of the smaller boilers in the plant, designed to operate at lower steam pressure and temperature. With a capacity of 300,000 lb per hour it is arranged to carry the entire steam load of one of the 30,000-kw turbine-generators so that operation may be on the unit principle. Pulverized coal with the direct-fired system and a slagging furnace are employed. Preliminary studies indicated a saving of approximately $20,000 per year through adoption of improved steam conditions alone and this is likely to be amplified by more economical loading permissible with the new arrangement.

THE Picway Station of the Columbus Railway Power & Light Company, at Groveport about twelve miles south of Columbus, Ohio, was constructed in 1926. The initial installation comprised two 30,000-kw turbine-generators and six 14,700 sq ft cross-drum boilers designed to operate at 350 lb steam pressure and 710 F at the superheater outlet. Refractory furnaces were employed and firing was with multiple-retort stokers 41 tuyeres long, an unusually long stoker for that date.

At the time the plant was built five of the boilers were completely equipped but the sixth, although installed, was not equipped, as the five provided ample steam-generating capacity for the load. Another station was then being operated in conjunction with Picway.

Subsequently it was found that the air-cooled settings, as originally installed, resulted in rather high maintenance and, in addition to this, considerable trouble was experienced with slag at the higher ratings. Therefore, in 1930 three of the boilers were equipped with water-cooled side walls. Until late in 1933 no additions or further changes of a major character were made.

More recently, however, it has been found desirable to shift more of the load from the other station to Picway, because of the latter's better economy. This led to an investigation being made as to the possibilities of increasing the steam pressure and temperature. The analyses indicated that if one of the 30,000-kw turbine-generators were to be operated at increased pressure and temperature (around 400 lb and 750 F) there would result an estimated saving of approximately $20,000 per year on this item alone. However, it was not found feasible to reconstruct the existing steam-generating units to meet the proposed new steam conditions.

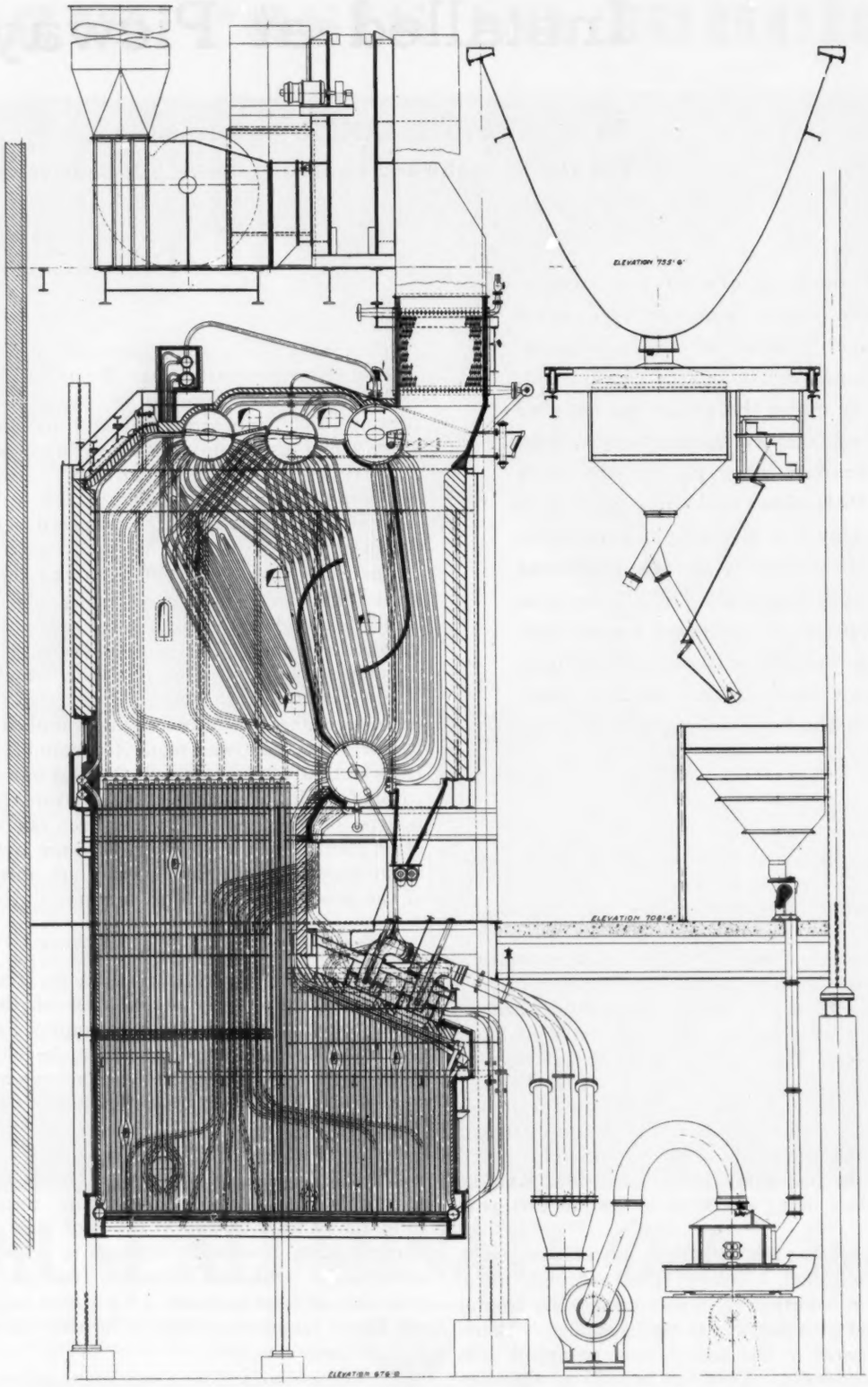
Therefore, in order to effect this saving, and at the same time secure increased boiler capacity, it was decided to replace the sixth boiler, which could be used in another station, by a new steam-generating unit suitable for the improved steam conditions. This would permit operation on a unit basis with all the steam for one 30,000-kw turbine being supplied by the new boiler. Provision was made for suitable interconnections so that when the new boiler was out of service the turbine could be operated with steam from the old boilers, or vice versa. It has been our experience in other plants that we get a very high use factor with such an arrangement and consequently are able to get most of the possible savings for a minimum investment.

Pulverized Coal and Slagging Furnace for New Unit

Furthermore, it was decided to fire the new boiler with pulverized coal and, in view of the conditions under which it would operate, to employ a slagging type of furnace. The job of removing the old boiler and installing the new one had to be done in a space of $26\frac{1}{2}$ by 29 ft without interruption of service.

This new boiler unit has just recently been completed and was placed in operation this summer. The boiler is of the C-E four-drum, multiple-circulation type with a completely water-cooled slagging furnace, having tubes on all sides as well as the floor, and six turbulent burners firing downward through a refractory water-cooled arch. Ohio coal is burned, averaging 7.2 per cent moisture, 10.2 per cent ash, 1.8 per cent sulphur, 2350 F ash-fusing temperature and a heating value of 11,600 Btu per pound as fired.

The unit is designed for a continuous output of 300,000 lb of steam per hour at 400 lb operating pressure (450 lb designed pressure) and 750 F at the superheater outlet under which conditions the calculated heat release is 25,300 Btu per cu ft of furnace. The furnace walls, sides and rear, are 4-in. plain tubes backed by $2\frac{1}{2}$ in.



Section through new steam-generating unit

of firebrick, 3 in. compressed rockwool insulation and steel casing. The bottom has 4-in. fin tubes on 7-in. centers over which is placed 8 in. of stoker slag. The arch and upper front wall have 4-in. tubes with 9 in. of firebrick, 3 in. of rockwool insulation and steel casing. Molten slag is removed at one side through a slag spout and disposed of hydraulically.

An economizer of the fin-tube, continuous-loop design, without flanged connections, is placed immediately beyond the last pass and a regenerative type of air heater delivers preheated air to the burners and furnace at 388 F. The superheater is placed between the first and second tube banks just in front of the first baffle.

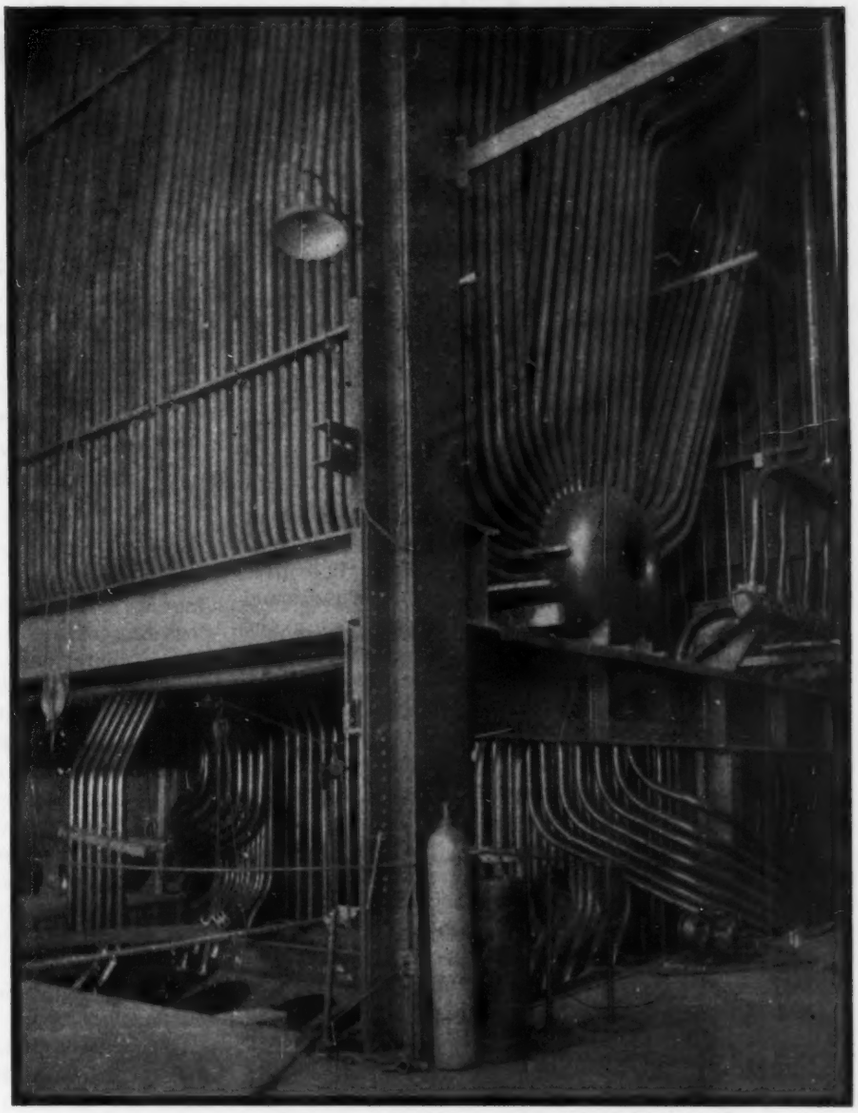
The heating surface is distributed as follows:

Boiler water heating surface,	18,300 sq ft
Water walls, bottom and arch,	6,870 sq ft
Economizer,	6,770 sq ft
Superheater,	4,100 sq ft
Air heater,	28,200 sq ft

Two ten-ton Raymond mills of the roller type supply the six burners. These mills, which are located at the basement level, receive coal from weigh hoppers on the firing floor which, in turn, are supplied through a traveling larry from an overhead bunker. The coal is dried in the mills with hot air and oil burners are provided for lighting off. The mills and exhausters are driven by variable-speed motors.

The furnace is suspended at the top and is free to expand downward. Reference to the cross-section will give an idea of the furnace wall circulation. Downcomers from the bottom boiler drum enter a front bottom header from which extend the bottom tubes as well as the front furnace walls. The bottom tubes terminate in a header at the rear which supplies the rear furnace wall. Downcomers on either side supply bottom headers which, in turn, supply water to the side wall tubes. These terminate in headers from which risers connect with the rear boiler drum. The rear and middle boiler drums are 42 in. inside diameter and the front and bottom drums 48 in. All are fusion welded. A special feature of this installation is the arrangement of firing through the arch.

The engineering was done by The United Light and Power Engineering & Construction Company of Davenport, Iowa and the complete steam generating unit was furnished by Combustion Engineering Co., Inc.



Construction view from front of boiler before casing was in place

Proportionate Coal Utilization

From figures collected by the U. S. Bureau of Mines and the U. S. Geological Survey it appears that the industrial consumption of bituminous coal for May 1934 totaled 21,605,000 tons distributed as follows:

Electric utilities	11.6 per cent
By-product coke ovens	21.6 per cent
Beehive coke ovens	0.4 per cent
Steel and rolling mills	5.2 per cent
Coal-gas retorts	1.0 per cent
Cement mills	1.7 per cent
Other industrials	30.0 per cent
Railroads	28.5 per cent

This is exclusive of coal mine fuel and bunker fuel which together totaled 387,000 tons. It was also exclusive of stocks which among the electric utilities averaged slightly over two months' supply and about one month's supply for industries in general.

D. L. Gaskill for twenty-five years Secretary-Treasurer of the National District Heating Association retired at the annual convention of the association, June 12–15.

Balanced Regulating Valves

By I. E. CHURCH

Investigating Engineer,
Duquesne Light Company

That so-called "balanced" valves, while balanced under certain conditions are often not balanced under other conditions, has been amply proved by operating experience. Differential pressure across or flow through the valve greatly influences its action. The article summarizes the results of an investigation of the subject by the Duquesne Light Company and shows how conditions of unbalance were corrected in a number of cases.

IN THE literature pertaining to automatic pressure-reducing or regulating valves, there frequently occurs the word "balanced" intending to convey to the reader the thought that the valve is not affected by the differential pressure across it or the flow through it. This intent is accepted by the trade and appears in most literature without any supporting statement or data, while, on the other hand, great stress is placed on the means of controlling the action of the valve. A casual study of the design and operation of the usual type of reducing or regulating valve will lead one to the thought that the weight of the moving parts, friction, flow through the ports, impact and reaction of the flowing medium all must affect, and do affect, the operation.

Discussion of this condition with representatives of the manufacturers of several well-known valves has brought out the fact that there is a great deal to be learned concerning the unbalance of so-called balanced valves. These discussions have come about not because we academically decided that balanced valves are unbalanced, but because of the many operating difficulties which we have encountered in the use of balanced valves and which could be traceable only to some condition of unbalance. After investigating and correcting many cases of this type, we are of the opinion that there are practically no balanced valves. There are many valves which may be balanced under certain conditions of pressures and flows but which under other conditions are woefully lacking in this respect.

After having surveyed the many cases of difficulties with which we have been confronted in the past several years, it seems that some of the information and data collected may be of general use and we have, therefore, endeavored to set them down in the present article.

Regulating Characteristics

The one characteristic assumed necessary for a regulating valve in the past has been that it be balanced at all positions and at all differential pressures.

When valves are checked in service, however, it will be found that some remain nearly balanced at small differentials of pressure; others will be nearly balanced at certain flows with higher differentials of pressure; some at high differentials and small flow; while others will be balanced only after the valve has opened appreciably. A valve may work satisfactorily for years, when changed operating conditions cause it to be very unsatisfactory.

Operating Requirements

Every regulating valve, to operate properly, must have a compensating force to oppose the initial operating impulse, otherwise the valve will go to the extreme position with every slight change from normal. On remote-controlled valves operated by air, water or oil from a master pilot valve where the compensation is provided at the pilot valve, the regulating valve may operate satisfactorily whether balanced or not, but if unbalanced, this unbalance should be in one direction only. The unbalanced direction must also depend on the operation. A valve normally open should have the unbalanced forces within it due to flow tending to open the valve, while one normally closed should have the unbalanced force resist any external opening force. The weight of the moving parts should also be in the same direction as the unbalanced forces, otherwise there may be a point of reversal in the direction of the resultant forces.

With direct-controlled valves operated by weights, springs or diaphragms, it is imperative that the forces inside the valve do not reverse in direction during the cycle of operation, and for satisfactory operation the internal forces should increase with the operating force.

Thus it is seen that a truly balanced valve is seldom if ever necessary under any condition; rather what is needed is a valve that is uniformly unbalanced a proper amount and in the desired direction.

Many valves have springs to assist in attaining these results but the forces inside often nullify the spring action at one point and assist it at another. So it is necessary that the forces inside the valve change as little as possible or increase uniformly.

Shape of Ports in Cylinder Types of Valves

Of the numerous types of plungers used in regulating valves, the open cylinder type seems to be the more reliable for most conditions. Yet for this type the size and shape of ports, valve travel, direction of flows and capacity need to be carefully proportioned to the specific conditions.

In cases where the normal operation requires the valve to be considerably open, a straight square port is generally satisfactory. Where the operation may demand close regulation from the closed position to full open, the area of the ports should be proportioned to the flow so as to require an increasing proportional

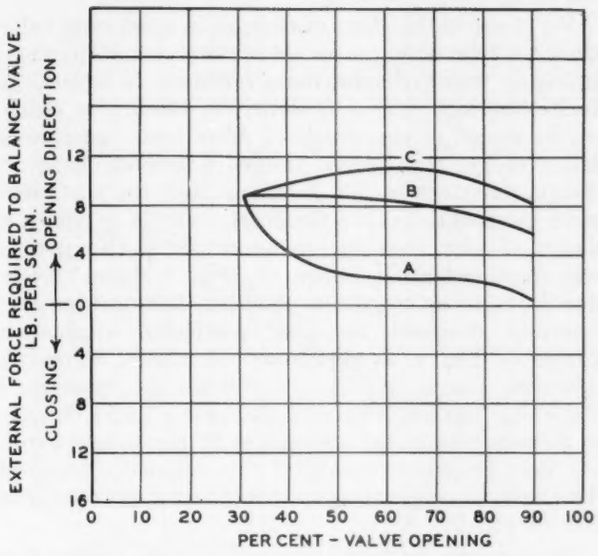


Fig. 1—20 lb differential across boiler feed regulating valve

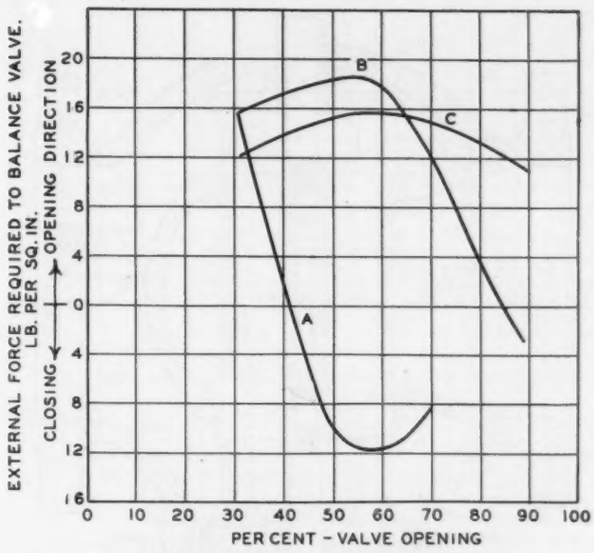


Fig. 2—50 lb differential across boiler feed regulating valve

movement as the valve nears the closed position. Where the differential is small, a "V" type port is adequate. If it is desired to have the flow proportional to the travel, the area of the opening and the pressure drop must both be taken into consideration, the flow being directly proportional to the area of the port and the square root of the pressure drop across the ports.

Another important consideration is the volume and shape of metal in the flow stream and the chance of impingement, cavitation and eddy current effects.

A valve may require a certain force to lift the weight of the plunger off the seat and an additional force to open against the cavitation effect of the flow. As it opens farther, the cavitation effect is decreased by the building up of pressure within the valve body. As the opening progresses there is an impingement effect tending to open the valve, the flow past the guide legs produces an eddy or low-pressure effect which acts to close the valve. All these forces acting to assist or oppose each other increase and decrease as the valve is opened. Depending upon the differential pressures, quantity of flow and pressures involved, they make the operation of the valve hard to predict in advance. In general, however, it is desirable to prevent as far as possible any chance for impingement and eddy currents by making the edges of the ports sharp and tapering any other projections in the line of flow. However, it is sometimes possible to take advantage of these effects to make the valve more stable.

Figs. 1 and 2 show the effect of port changes on an open-cylinder type boiler feedwater regulator. This valve, operating under a variable differential of 20 to

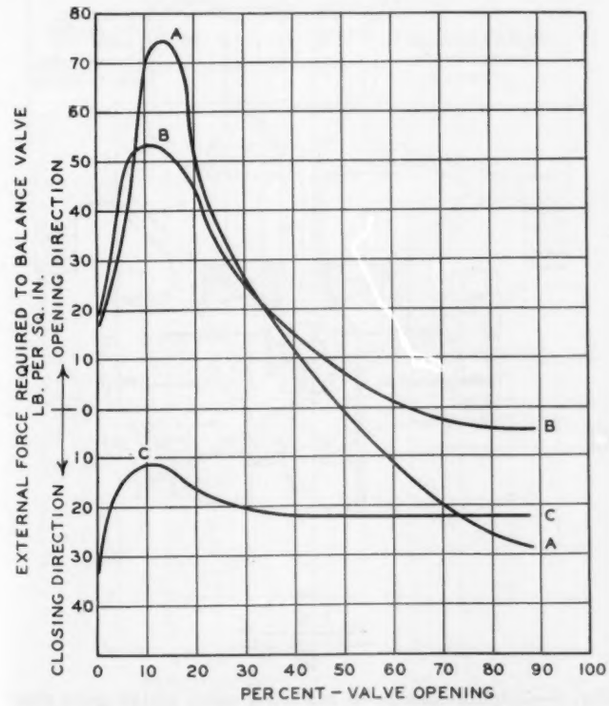


Fig. 3—Effect of changes in small turbine governor valve

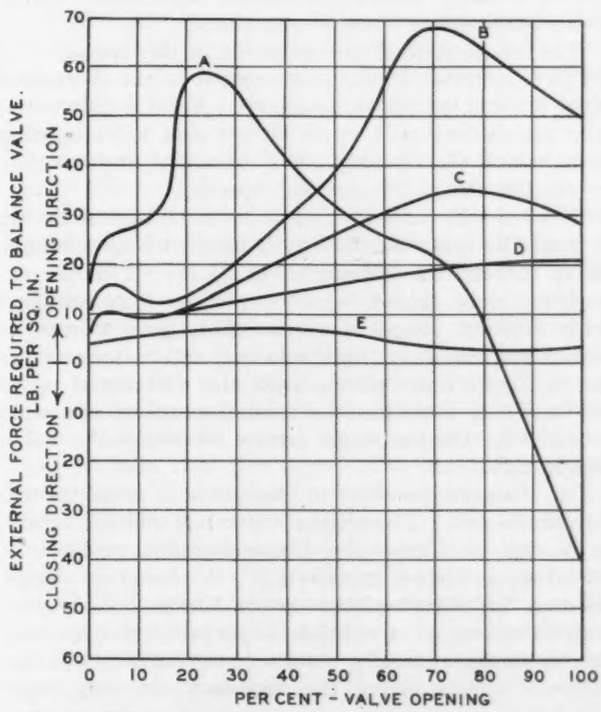


Fig. 4—Effect of changes in a pressure-reducing valve

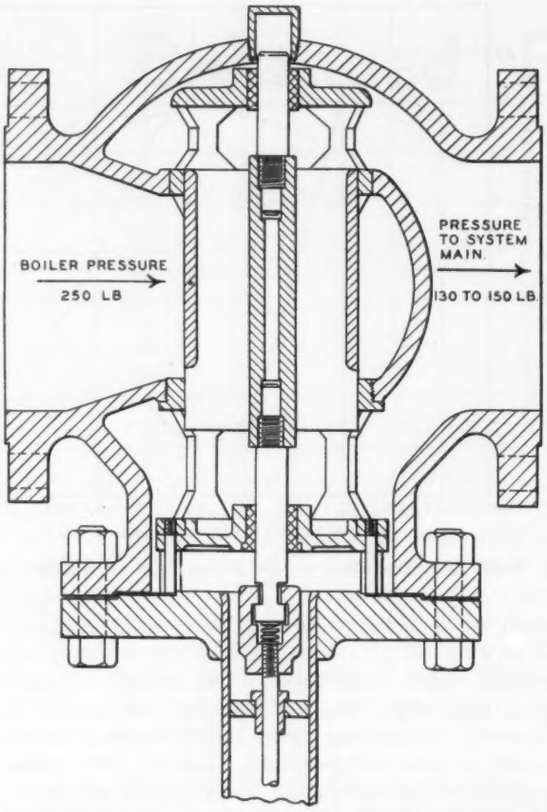


Fig. 5—Reducing valve as altered to give characteristics shown by Curve *C*, Fig. 4

50 lb, had the characteristics of Curve *A*. It will be noted that as the valve opened the flow tended to assist the opening force at 20 lb differential, while at 50 lb differential the forces due to flow actually changed in direction. Analysis of the forces involved indicated that changes in the contour of the ports to direct the flow downward would give better operation. Curve *B* shows the effect of the changes made.

There is a marked improvement in the operation at 20 lb differential, though, on account of the downward slope it is not entirely satisfactory. At 50 lb differential it is satisfactory only up to 65 per cent valve opening after which the opening force decreased and actually reverses again at 95 per cent opening.

Tests of this valve at 15 lb differential indicated that it would be quite satisfactory if used with an auxiliary valve to keep the differential at 15 lb. With the experience thus gained, another plunger was obtained with different shape of ports. This gave results as shown in Curve *C*. This shows very satisfactory results up to 70 per cent opening with any differential up to 50 lb, which is within the normal range of operation required for the particular service for which this valve was installed.

Fig. 3 shows the effect of changes on a small turbine governor valve. The original valve had a characteristic as shown in Curve *A*. Changes made resulted in operation as shown in Curve *B*. A change in design resulted in characteristics as in Curve *C*. As this turbine seldom operates below 30 per cent valve opening, the operation as finally obtained was satisfactory, the governor spring giving the necessary drooping characteristics.

Fig. 4 shows the effect of changes in a reducing valve. Curve *A* represents the action of the valve as originally installed, which characteristic obviously produced extreme hunting. Curve *B* shows the effect of a change in the design of the plunger. After some experiments failed to get the desired results, a second change in design, as shown in Fig. 5, except that the port edges were not rounded, gave the characteristics as shown in Curve *C*. By rounding the port edges, this plunger was improved as in Curve *D*. Fig. 6 shows this reducing valve as originally installed, having been very carefully designed for this particular application. Curve *A*, Fig. 4, as previously mentioned, shows the operating characteristics. Of course, the capacity of the valve was reduced with the new plunger, making it necessary to install two valves in parallel to handle the load for which one valve was originally designed. This valve was operating to reduce steam pressure from 250 to 130 lb.

It is interesting to note the effect of this same type valve when reducing steam from 130 to 10 lb. This is shown in Curve *E*, Fig. 4. The drooping characteristic noted after 40 per cent opening is due partly to slightly shorter guide webs in the plunger and partly to the choking up of the valve due to the large increase in volume with the large reduction of pressure.

It will be noted that the curves of all valves discussed have this same general trend, a peak being encountered at some point in the travel. This leads to the conclusion that the valve bodies of all regulating reducing valves

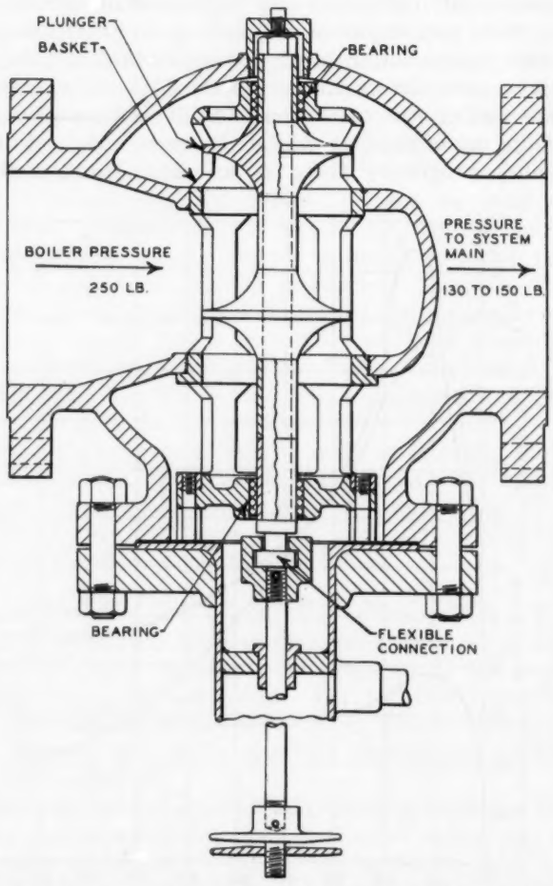


Fig. 6—Original design of reducing valve which gave characteristics shown by Curve *A*, Fig. 4

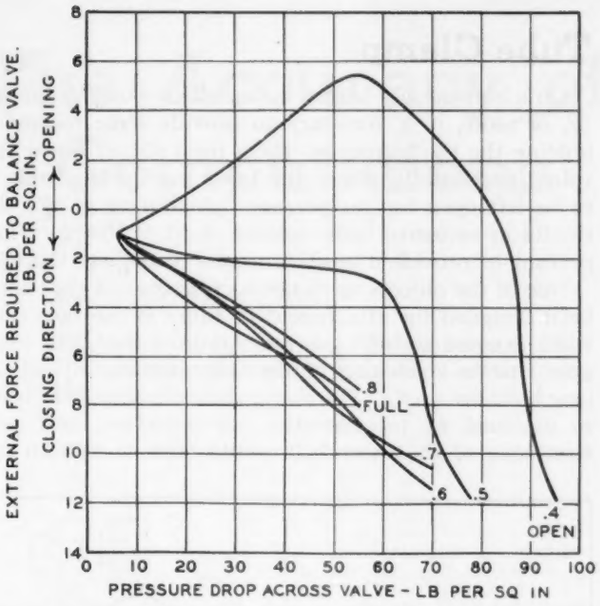


Fig. 7—Unstable characteristics of boiler feed regulating valve due to shape of ports

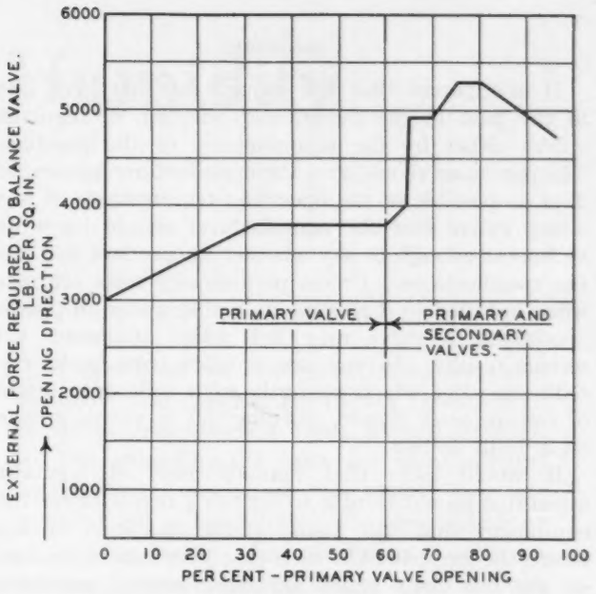

EXTERNAL FORCE REQUIRED TO BALANCE VALVE. LB. PER SQ. IN.
OPENING DIRECTION
PER CENT - PRIMARY VALVE OPENING
PRIMARY VALVE
PRIMARY AND SECONDARY VALVES.

Fig. 9—Characteristics of large turbine governor primary and secondary valves

should be very much enlarged over the sizes now in common use.

In general it seems that the capacity of standard reducing valves should be limited to about half their present rating. Much better results were obtained by reducing the port areas of a 6-in. valve to give a flow equivalent to the rating of a 4-in. valve. In another case a 12-in. valve was reduced in capacity equivalent to a standard 8-in. valve. As most valves are now constructed, the outlet end is restricted by the internal parts preventing the free outlet of the fluid. For standard manually operated valves this is unimportant but for automatic regulating valves it causes poor regulation from approximately half to full open position.

Variable Pressure Drops

Another point to be considered is the variations in pressure drop across the valve.

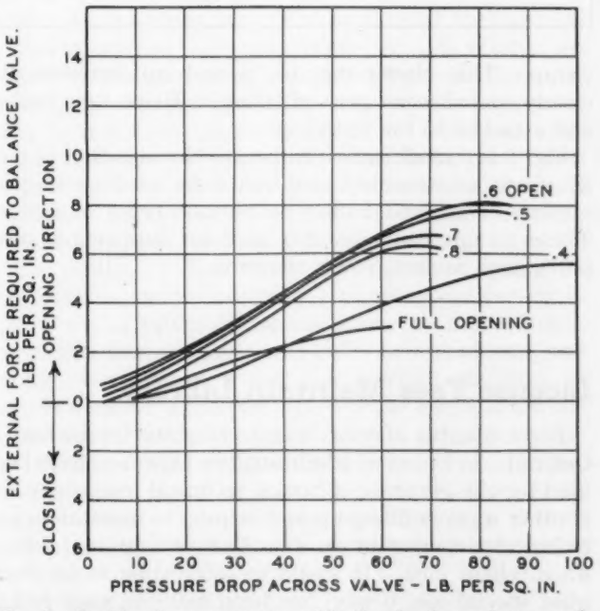


Fig. 8—Stable characteristics of boiler feed regulating valve

A steam auxiliary may have a throttle pressure varying from 100 to 200 lb. Most valves have a very large variation in the force required to open and close the valves with this type of service. The force often changes in direction between the minimum and maximum position, tending to assist the operating force at one differential and oppose it at another differential.

It is practically impossible to make equipment work satisfactorily in parallel with valves of this type, the tendency being for the equipment to hunt. To improve the operation of valves, springs are often used to compensate for a change in the direction of the force. While this will improve the operation where the change is uniform, it generally helps for only part of the travel beyond which it may make conditions worse.

Figs. 7 and 8 show the characteristics of two valves of the same type, the only difference being in the shape of ports. The valve represented in Fig. 7 would be unstable under practically all conditions. Many valves of this type are in operation, but in most cases it is necessary to use a hand throttle valve to limit its maximum effect. The force changing in amount and direction as the valve is opened and closed requires a hand adjustment for any large change in load.

Fig. 9 shows the characteristics of a large turbine; oil-operated, governor consisting of a primary and secondary valve operated by an oil cylinder on the primary valve. The turbine operated satisfactorily on the primary valve alone but when the load increased to require the opening of the secondary valve, there was a tendency to hunt. By referring to the curve, it will be seen why this is so. The peak of the opening force comes at about half open secondary valve position after which the force decreases. Springs are installed to counteract some of these forces but they are not sufficiently effective. A change in the linkage between the primary and the secondary valves and the addition of another spring would help, but the real solution is a different type of secondary valve plunger or an independent operating cylinder for the secondary valve.

Conclusions

It is apparent that not enough care has been given in the past to the design and selection of regulating valves either by the manufacturer or the purchaser. The purchaser should give the manufacturer as complete data as possible of the operating requirements of regulating valves and the manufacturer should know and be honest enough to say whether his product will meet the specifications. Unless performance tests are made when installed to determine its action under all possible conditions, a valve may fail years afterward with serious results. In one case a valve stem broke on a reducing valve which promptly went wide open instead of closing as it should, putting 150 lb steam pressure on a 10-lb system.

It would seem that manufacturers of regulating apparatus should be able to furnish a regulator for their equipment that will assure stable operation at least where the equipment is such that they can be operated on the test floor under normal operating conditions. A series of tests similar to the ones described would give valuable data that could readily be applied to all equipment.

In general there are certain fundamental conditions that apply to all pressure-regulating equipment, the most important being that any unbalance be in one direction only. For the best operating conditions, it is also highly desirable that the magnitude of unbalance increase with the flow.

Fan Reaches Five-Year Mark in Continuous Operation

With nearly five billion revolutions to its credit, a fan located on the roof of General Electric's Pittsfield Works recently completed its fifth year of uninterrupted operation in a life test "to destruction."

The fan, one of a type built to cool the coils of power transformers, is still running, with engineers checking it at frequent intervals, waiting for the time when it will wear itself out. Thus far, however, they have observed no indication that the fan, which differs but slightly from those used in home and office, is reaching the limit of its endurance. It is being allowed to run until it goes to pieces in order to determine what points, if any, in its design or construction might be improved to provide even greater durability and dependability.

T.V.A. Acquires Knoxville Properties

Announcement comes from the Tennessee Valley Authority that it has completed arrangements for the purchase of entire properties (exclusive of electric railways and one transmission line) of the Tennessee Public Service Company serving Knoxville and twenty-seven other communities. These communities will be served by the T.V.A. with power generated at Muscle Shoals. The purchase price is reported as $6,088,000 and the bonds of the company advanced from a low of 44 at the beginning of the year to 95½.

Tube Clamp

On a horizontally baffled boiler with a slope of 2 in. in 12, or more, it is necessary to provide some means of holding the tile to prevent them from sliding down the tubes, particularly where the lower end of the baffle is to be left open for gas passage. A shifting of the tile results in excessive baffle leakage so it is therefore important to provide a positive means of holding the tile.

One of the objections to the various clamps that have been designed for attachment of tubes is the fact that when exposed to high gas temperatures they lose their grip, due to stretching of the bolt, particularly where long bolts are used. The clamp shown in Fig. 1 has been so designed as to eliminate this objection, and any stretching of the short bolt would tend to tighten the clamp. This clamp can be passed up between the closely spaced lower rows of tubes on Heine type boilers and attached to the third row.

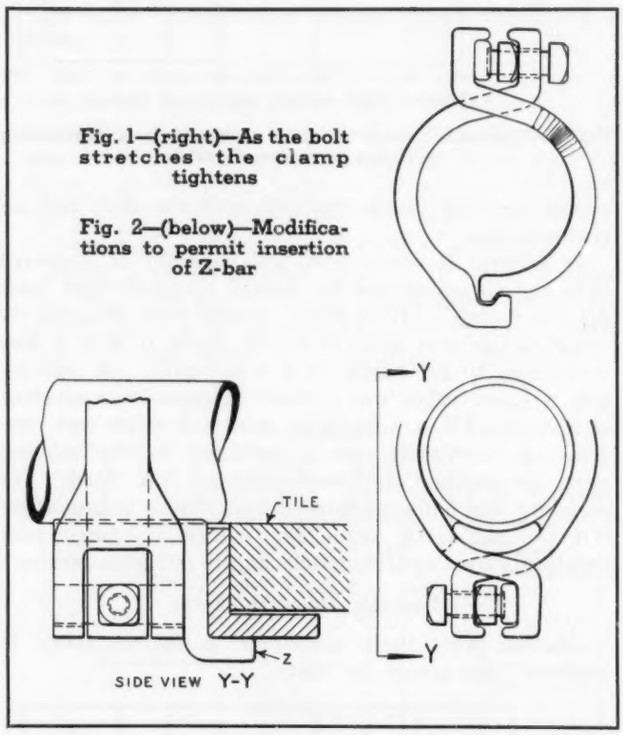


Fig. 1—(right)—As the bolt stretches the clamp tightens

Fig. 2—(below)—Modifications to permit insertion of Z-bar

Fig. 2 is a modification to permit the insertion of part *Z*. Such an assembly could then be used to support vertical or inclined baffles on various types of boilers. These clamps could be also used for supporting other parts, such as soot blower elements.

License Fees Maintain Library

For a number of years engineers' state license fees in Colorado, in excess of administrative expenses, have been used for the purchase of books, technical magazines and in other ways building up and helping to maintain a live technical department in the Denver Public Library. An excellent idea. It would be interesting to ascertain what special use, if any, has been made of such fees in other states.

The Accuracy of Humidity Computations

By C. HAROLD BERRY

Professor of Mechanical Engineering, The Harvard Engineering School, Cambridge, Mass.

In combustion computations, we need to know the specific humidity (pounds of vapor accompanying each pound of air). In the selection of fans for combustion equipment, we need to know the air density (pounds of "dry" air per cubic foot of atmosphere). In studying fan performance, we need to know the mixture density (pounds of air-plus-vapor per cubic foot of atmosphere). The relative humidity is involved in the usual methods of computing these quantities.

How accurately do we secure these results from observed data? This article presents part of an extended survey of this question, and indicates that the attainable accuracy is ordinarily lower than is commonly assumed.

IN ANY engineering study, the accuracy of results is intimately associated with the precision of the observed data, and it is important to know how the two things are related. On the one hand, we wish to know how precise the instrumental work must be to yield results of a stated accuracy, and, on the other hand, we wish to know how accurate our results are when based upon observations of known precision. In a general way, the accuracy of results is indicated by the number of significant figures presented. While there are no rigid rules, it is generally recognized that a reported value represents certainty in all but the final significant digit, and not very great uncertainty in this final digit. For example, if the relative humidity is stated as 0.547, it is presumed that we are certain of 0.54, and that the final 0.007 may be subject to uncertainty to the extent of one or perhaps two units either way. That is, we feel sure that the result lies between 0.546 and 0.548, or at the worst between 0.545 and 0.549.

A given error in an observed quantity will produce a related error in the computed result, and a study of the relation between observed data and computed result will serve to indicate the relation between these two errors. Such a study may be made through the formulas or charts relating the quantities. In this study, the relative errors have been computed from the formulas relating the various quantities, one of these formulas being Ferrel's empirical equation[1] for the wet- and dry-bulb psychrometer, and the others being established by definition. A brief survey indicates that the results would not have been materially different if Carrier's formula[2] had been used instead of Ferrel's.

The results of this study for the four quantities mentioned in the introductory paragraph are presented in the form of tables giving the errors in observed data (dry-bulb temperature, wet-bulb temperature, and barometric pressure) which will produce an error of unity in a stated significant figure of the result, when the computations are carried through on the assumption that the given data are free from error. For example, if the data are stated as $t_d = 80$, $t_w = 68$, $B = 29.47$, we can compute values of the results to any desired number of significant figures, merely as a matter of simple arithmetic. Now, if the dry-bulb temperature was in error, so that its true value should have been 79.7, obviously the result computed on the basis of 80 will be wrong. What will be the error resulting from the false assumption that 80 is the correct value? Or put the matter another way. Suppose that a given result, computed on the assumption of accurate data, turns out to be 0.0786. How much error in the dry-bulb temperature would alter this value to 0.0785 or 0.0787? It is in this latter form that the results of this study have been cast, in the belief that they are thereby made more intelligible and more useful.

In each case it is necessary to present results over a range of values of the given data. For example, if the wet-bulb depression is zero, the relative humidity will be computed as unity, regardless of the barometric pressure. If the wet-bulb depression is not zero, however, all computed results will be somewhat affected by the barometric pressure. Moreover, the relation between instrument error and result error will vary with the temperature. Accordingly, the results are presented for a number of points fairly well scattered through the usual range of atmospheric conditions. Extremes of high and low temperature are not presented. It is believed that this restricted range is sufficient to indicate the situation and its bearing upon engineering applications in the fields of combustion and ventilation. The principal object is to draw attention to the situation, rather than to present numerical data, for a simple

[1] Annual Report Chief Signal Officer, U. S. Army, 1886, Appendix 24.
[2] Transactions A.S.M.E., vol. 33 (1911), pages 1005 and 1024.

inspection of charts or formulas will serve to indicate the relative error in any given case.

Relative Humidity

Relative humidity varies from zero to unity, or from zero to 100 per cent. It is often reported to three significant figures, but Table I indicates that comparatively small errors in wet- and dry-bulb temperatures will give an error of unity in the second significant figure. Errors one-tenth of those given in the table will produce unit errors in the third digit.

TABLE I—RELATIVE HUMIDITY

Errors in {dry-bulb temperature, deg F / wet-bulb temperature, deg F / barometer, inches of mercury} to produce unit error in the second digit of relative humidity, for example, an error of ±0.01 in a value of 0.625.

Wet-bulb Depression	Dry-bulb Temperature 100	80	70	60	50	40
	0.28	0.23	0.20	0.18	0.15	0.12
0	0.28	0.23	0.20	0.18	0.15	0.12
	Infinity (that is, the barometer has no influence)					
						0.15
5						0.13
						1.4
	0.38	0.32	0.29	0.26	0.22	
10	0.34	0.29	0.24	0.21	0.18	
	5.0	2.8	2.0	1.4	0.98	
	0.56	0.50	0.45			
20	0.43	0.34	0.30			
	2.6	1.4	1.0			
	0.83					
30	0.53					
	1.7					

These values are for a 30-in. barometer. For lower pressures, the temperature errors are slightly larger. The barometer errors are the same for all pressures.

A survey of this table indicates that, to be sure of two significant digits in relative humidity, the thermometers must be read with errors ranging from one- to eight-tenths of one degree F. Inasmuch as usual humidity observations do not approach this degree of precision, it appears that we are certainly never justified in reporting relative humidity to three significant digits, and that we are often not sure of two digits. An error of half a degree in either thermometer will produce an error of from 2 to 4 in the second digit of relative humidity. It is deceptive to report a value of 0.524 when we can only be sure that the value lies somewhere between 0.49 and 0.55. A good argument might be presented for reporting 0.52, but an equally good argument would justify reporting only 0.5.

Specific Humidity

The pounds of water vapor accompanying one pound of air varies from about 0.0030 at low temperatures to about 0.0400 at high temperatures and high relative humidity. It is often reported to four decimal places. Table II indicates that this implies a degree of instrumental precision higher than is usually attained, especially in the case of the wet-bulb thermometer. Errors ten times those given in the table will correspond with unit error in the third decimal place of specific humidity, and will be more in line with usual psychrometric observations.

Since an error of one- or two-tenths of a degree F in the wet-bulb temperature is usually much smaller than is probable in ordinary work, it would appear that there is no justification for reporting specific humidity beyond the third decimal place. That is, a value of 0.0326 is deceptive; the value 0.033 would be a more truthful report of the known facts. Fortunately, this degree of accuracy is adequate for most work.

Air Density

The pounds of air in one cubic foot of atmosphere varies from about 0.0800 down to 0.0500 or lower for low barometer readings. It is quite common to see values reported to four significant digits, for example, 0.07863. Table III indicates that this practice cannot be justified, since such a result demands instrumental errors one-tenth of those given in the table.

It appears that values dependable in the third significant digit can be secured with quite ordinary instrumental technique, but that the fourth digit would call for highly precise thermometry.

TABLE II—SPECIFIC HUMIDITY (POUNDS OF VAPOR PER POUND OF AIR)

Errors in {dry-bulb temperature, deg F / wet-bulb temperature, deg F / barometer, inches of mercury} to produce unit error in the fourth decimal place of specific humidity, for example, an error of ±0.0001 in values ranging from 0.0030 to 0.0400.

Wet-bulb Depression	Dry-bulb Temperature 100	80	70	60	50	40
	0.37	0.40	0.40	0.42	0.42	0.43
0	0.06	0.10	0.13	0.16	0.19	0.21
	0.07	0.13	0.19	0.27	0.38	0.56
						0.43
5						0.26
						0.71
	0.38	0.42	0.42	0.42	0.43	
10	0.08	0.13	0.16	0.20	0.22	
	0.09	0.19	0.27	0.38	0.56	
	0.40	0.42	0.42			
20	0.10	0.16	0.19			
	0.13	0.27	0.38			
	0.42					
30	0.13					
	0.19					

These values are for a 30-in. barometer. For lower pressures, the errors in dry-bulb temperature are substantially the same. The errors in wet-bulb temperature are slightly smaller. The barometer errors are much smaller, but not so much as to present any difficulties.

Mixture Density

The pounds of air-plus-vapor in one cubic foot of atmosphere varies from 0.0800 to 0.0600 or lower for low barometric pressures. This also is often computed to four significant digits, a practice that is condemned by Table IV.

TABLE III—AIR DENSITY (POUNDS OF AIR PER CUBIC FOOT OF ATMOSPHERE)

Errors in {dry-bulb temperature, deg F / wet-bulb temperature, deg F / barometer, inches of mercury} to produce unit error in the third significant digit of air density, for example, an error of ± 0.0001 in a value of 0.0743.

Wet-bulb Depression	Dry-bulb Temperature 100	80	70	60	50	40
	1.09	0.96	0.91	0.86	0.82	0.77
0	0.61	0.89	1.10	1.32	1.54	1.82
	0.042	0.041	0.040	0.039	0.038	0.038
						0.77
5						1.96
						0.038
	1.06	0.94	0.89	0.85	0.81	
10	0.76	1.11	1.33	1.59	1.85	
	0.042	0.041	0.040	0.039	0.038	
	1.03	0.93	0.89			
20	0.93	1.37	1.61			
	0.042	0.040	0.040			
	1.02					
30	1.16					
	0.042					

These values are for a 30-in. barometer. For lower pressures, the temperature errors are somewhat larger. The barometer errors are the same for all pressures.

It is interesting to note that the allowable errors in the wet-bulb temperature are comparatively large in this case. The dry-bulb temperature, on the contrary, must be determined with care. Since errors one-tenth of those given in the table would demand higher precision than is usually attained, the reporting of the fourth digit is not justified.

Where the Difficulty Lies

In all of the tables it is evident that the barometric pressure can easily be observed with more than adequate precision, assuming that the barometer is in good condition and that it is read by means of the usual vernier follower. It is not safe to assume that a barometer that merely looks good is really good. Seemingly trivial defects may easily produce errors as great as one-tenth of an inch. A barometer should be checked periodically against a standard instrument of the United States Weather Bureau. This organization is always ready and willing to cooperate in such checking.

The real difficulty lies in thermometry. This resolves itself into three distinct questions. 1. How closely does the temperature of the thermometer approximate the temperature it is supposed to indicate? 2. How closely does the thermometer indicate its own temperature? 3. How closely can the indication of the thermometer be observed? This is not the place to discuss these important questions, but a few considerations deserve mention.

TABLE IV—MIXTURE DENSITY (POUNDS OF AIR-PLUS-VAPOR PER CUBIC FOOT OF ATMOSPHERE)

Errors in {dry-bulb temperature, deg F / wet-bulb temperature, deg F / barometer, inches of mercury} to produce unit error in the third significant digit of mixture density, for example, an error of ±0.0001 in a value of 0.0732.

Wet-bulb Depression	Dry-bulb Temperature 100	80	70	60	50	40
	0.89	0.81	0.77	0.74	0.71	0.68
0	1.6	2.4	2.9	3.4	4.2	4.8
	0.042	0.041	0.040	0.039	0.038	0.038
						0.68
5						5.3
						0.038
	0.88	0.80	0.77	0.74	0.70	
10	2.0	2.9	3.6	4.2	5.0	
	0.042	0.041	0.040	0.039	0.038	
	0.87	0.79	0.76			
20	2.5	3.6	4.3			
	0.042	0.041	0.040			
	0.86					
30	3.1					
	0.042					

These values are for a 30-in. barometer. For lower pressures, the temperature errors are somewhat larger. The barometer errors are the same for all pressures.

A thermometer exposed to radiation from surrounding objects does not indicate the temperature of the air in contact with it. This error may easily amount to several degrees. It is therefore important that thermometers be equipped with radiation shields.

A thermometer that pretends to any degree of precision should be calibrated against unquestioned standards, and calibration corrections should be applied to all readings.

A thermometer can hardly be read to closer than one-fifth of its smallest division. Even this can be done dependably only by an experienced and careful observer. It is preferable to plan readings only to half of the smallest division. It would therefore appear that to secure reasonable accuracy in humidity work, thermometers should be graduated to fifths of one degree F, so that readings can be taken to one-tenth of one degree.

The difficulty of securing precise readings is greater with the wet-bulb thermometer than with the dry-bulb instrument.

The usual slap-dash method of swinging a sling psychrometer and taking a single snap reading appears to be definitely bad practice. Some form of aspirating instrument is greatly to be preferred. In such an instrument, the thermometers are protected by radiation shields, and readings can be taken without interrupting the flow of air over the thermometer bulbs.

A Possibility of Simplification

Inasmuch as the wet- and dry-bulb psychrometer, as ordinarily used, gives such large uncertainty in the value of the relative humidity, it may be that equally good results could be secured by using a good hair hygrometer to measure the relative humidity directly. This value, together with the dry-bulb temperature and the barometer reading, would yield all desired results. To what extent then would this provide a dependable system?

A good hair hygrometer permits readings of relative humidity to two significant digits, for example, 0.56, and the manufacturers of such instruments assure the author that they will hold their calibration for some years to within 0.03, that is, to 3 units in the second digit. Table I indicates that this corresponds to errors of less than one degree in the temperature measurements through most of the range covered. Accordingly, the hair hygrometer seems to present possibilities of results as accurate as those obtainable by the psychrometer in the absence of exceptionally precise thermometry.

Reporting Specific Humidity

Specific humidity, as noted in connection with Table II, should probably not be reported beyond the third decimal place. This degree of accuracy can be attained with errors in the dry-bulb temperature ranging from 0.7 to well over one degree F. The allowable errors in relative humidity range from 0.02 to 0.20, and the barometer errors would range from 0.6 in. upward.

In order to secure the air density with an error not exceeding unity in the third significant digit (compare Table III), the allowable errors in dry-bulb temperature range from 0.4 to 0.9 F, the allowable errors in relative humidity range from 0.02 to 0.14, and the allowable errors in the barometer range from 0.038 to 0.042.

For mixture density, an error of unity in the third significant digit (compare Table IV) allows dry-bulb errors ranging from 0.3 to 0.9 F, relative humidity errors ranging from 0.06 to 0.33, and barometer errors from 0.038 to 0.042.

TABLE V—VAPOR PRESSURE COMPUTED BY FERREL'S AND APJOHN'S EQUATIONS

Errors in {dry-bulb temperature, deg F / wet-bulb temperature, deg F / barometer, inches of mercury} as used in Ferrel's equation, to produce the same error in vapor pressure that results from the use of Apjohn's equation instead of Ferrel's.

Wet-bulb Depression	Dry-bulb Temperature 100	80	70	60	50	40
						+0.15
5						−0.09
						+0.9
	−0.05	+0.08	+0.13	+0.22	+0.27	
10	+0.01	−0.02	−0.05	−0.10	−0.15	
	−0.16	+0.24	+0.40	+0.65	+0.81	
	+0.05	+0.27	+0.43			
20	−0.01	−0.10	−0.20			
	+0.08	+0.40	+0.65			
	+0.24					
30	−0.07					
	+0.24					

These values are for a 30-in. barometer. For lower pressures, the values are smaller.

No values are given for zero wet-bulb depression because under this condition the equations are in exact agreement, and in fact no equation need be used.

Consideration of these results indicates that the use of the hair hygrometer does not reduce the necessity for great care in measuring temperature, but it does eliminate the more difficult of the two temperatures, the wet-bulb, from the problem. It remains necessary to measure the dry-bulb temperature with all attainable precision. The barometer, as before, presents no special difficulties, since it can easily be read with adequate precision. The hair hygrometer, it would appear, should give indications of sufficient accuracy.

It is therefore tentatively suggested that, if we are unwilling to apply highly precise thermometry to the wet- and dry-bulb psychrometer, we might just as well avail ourselves of the simpler process of using a thermometer, a barometer and a good hair hygrometer. The hygrometer should be recalibrated periodically to check its permanency.

The author makes this suggestion with some hesitation, because he has had no experience whatever with the hair hygrometer. He does feel, however, that the suggestion offers possibilities of simplification that are worth investigation.

Conclusion

The temperature of the atmosphere is 67.3 F. Its relative humidity is 0.547, or 54.7 per cent. Its density is 0.07968 lb per cu ft. Its specific humidity is 0.01694 lb of vapor per pound of air. This is a comforting array of figures, indicative of painstaking arithmetic, but do they compose a truthful statement? Probably not. It is a safe bet that we are not sure of the relative humidity to the second digit, to say nothing of the third. And it is almost certain that the fourth digits in the two last results are so gravely in doubt that it is deceptive to report them.

For data as usually taken from simple instruments, we must reduce the number of significant digits in our results. If we need results that are accurate to three or four digits, we must employ highly precise methods for measuring temperatures, and this involves difficulties of a high order.

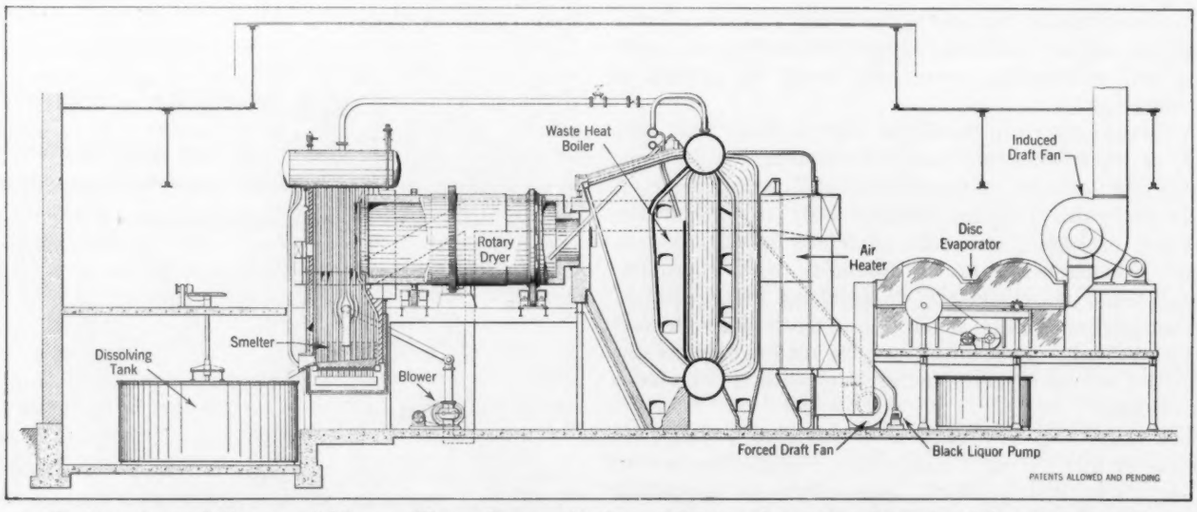
If we retain simple methods of measurement, we may as well make use of simpler methods of computing, and it is possible that we may be justified in using the hair hygrometer for ordinary test work.

Improved System Doubles By-Product Steam Recovery

Chemical recovery in soda and sulphate paper mills has long been practical and waste heat recovery from these processes is not new; but with the older systems the steam produced amounted to a maximum of 4000 to 5000 lb per ton of pulp made. By means of the Improved Murray-Waern System, perfected through the recent association of Combustion Engineering Company, Inc. and the D. J. Murray Manufacturing Company of Wausau, Wis., it is now possible to produce 10,000 lb of high-pressure steam per ton of pulp made. How this is accomplished is shown in the accompanying sketch.

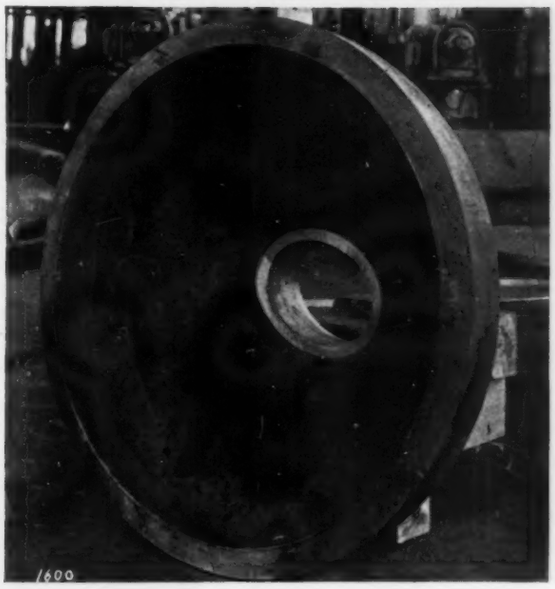
The black liquor, after passing through a multiple-effect evaporator, enters the disc evaporator. From here it is pumped to the rotary dryer through a water-cooled pipe. In the rotary unit the liquor is dried and the combustible element partly burned out. The residue is delivered directly to the smelter with no intermediate handling. In the smelter the remainder of the combustible is burned out and the chemical ash fused and drained to the dissolving tank. The gaseous products of combustion pass through the dryer, the waste heat boiler, the air heater, the disc evaporator and through the induced-draft fan to the atmosphere. The heat of combustion, other than that required to evaporate the moisture, is recovered in the form of high-pressure steam in the smelter and the waste-heat boiler.

In some previous designs attempts at cooling have been made by providing water pans to produce hot water, but the substitution of steam generating water walls accomplishes equal cooling and recovers a greater amount of heat in the form of high-pressure steam. The substitution of water walls for refractory in the smelter also reduces maintenance. Moreover, the water-cooled and air-scaled lip at the end of the rotary drier permits it to project directly into the smelter so that the black ash is automatically delivered onto the smelter hearth. Thus excess air is excluded and manual labor at this point with its attendant hazards is eliminated. The smelter roof is designed as an explosion door to give protection against explosion.

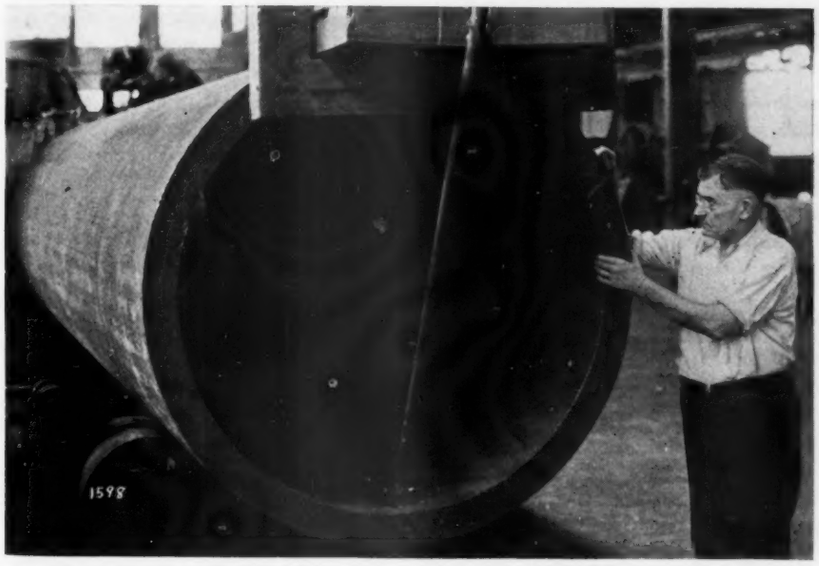


Section through Improved Murray Waern System for by-product recovery in soda and sulphate paper mill

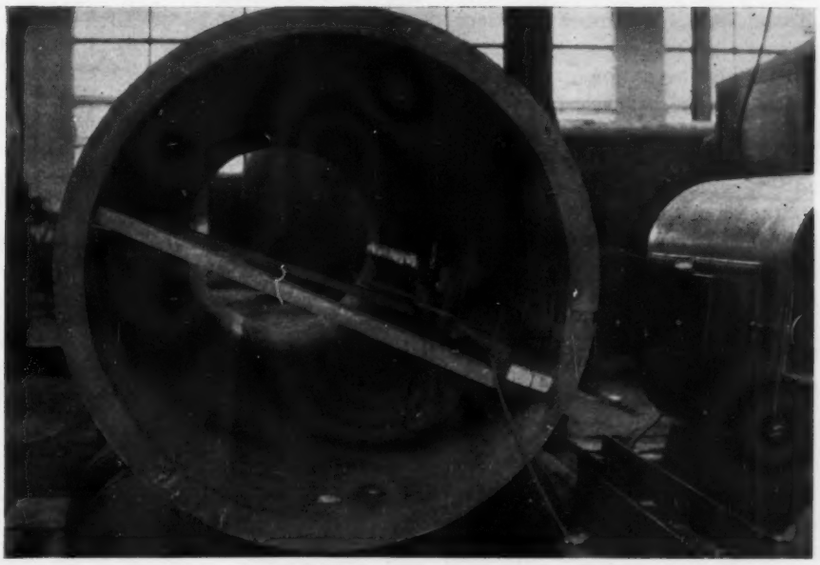
FUSION WELDING FOR HIGH PRESSURES



One of the heads for the main steam drum of the Firestone boiler. This is formed from a flat disk



The 300,000 lb per hr 1400 lb pressure boiler now being built for the Firestone Tire & Rubber Company's plant at Akron, Ohio, has a main steam drum 54 in. inside diameter, 23 ft long and 4 in. thick. To date this is the highest pressure boiler drum to be fusion welded



X-Ray inspection of fusion-welded drum for 15,500 sq ft 650 lb boiler being built for the Westinghouse Electric & Manufacturing Company

Photographs taken at the Hedges-Walsh-Weidner shops of Combustion Engineering Company, Inc.

Central Station Capacity

Viewed from the standpoints of normal increase in load, capacity-use factor, load factor, peak demand, necessary reserve and provision for system growth, the study leads to the conclusion that there is no evidence of inflation of generating capacity, within the central station industry as a whole, during the period from 1900 to 1929. It is pointed out further that much of the apparent excess in capacity, as indicated by the total figures, consisted of obsolete equipment which was retained through unwillingness to write off.

WHETHER there is actually an excess of generating capacity in central stations has of late been a much debated question. Therefore, a study by F. G. Tryon which forms a chapter in a book just issued by the Brookings Institution, Washington, D. C., entitled "America's Capacity to Produce"[1] is both pertinent and timely. The author approaches the problem with a view to all the factors involved and his conclusions appear to answer definitely the question as concerns 1929 capacity, at least.

It appears from statistics given that in the period 1902 to 1930 the generating capacity of central stations increased twenty-seven fold, or approximately ten per cent per year. The output increased still more rapidly, or about thirty-six times. The capacity-use factor $\left(\frac{\text{kilowatt-hours generated}}{\text{capacity in kilowatts} \times 8760}\right)$ has been gradually improving, having increased from 25.7 per cent of rated capacity for the five-year period, 1902–1907 to 37 per cent in 1929.

As is pointed out, the difference between the theoretical and the practically attainable capacity is much greater in the electric power industry than in most other lines of production because of the effects of load factor, limitations of and seasonal stream flow in hydro plants, the necessary reserve capacity to guard against outage and insure service at all times, and finally provision for system growth.

While the load factors $\left(\frac{\text{kilowatt-hours generated}}{\text{peak load in kilowatts} \times 8760}\right)$ for different systems and stations vary greatly, the average for the United States in 1929 was around 51 per cent which means that nearly twice as much capacity was in use at the time of the peak as on the average for the year as a whole. Looking at it from another angle, the peak of 20,500,000 kw for 1929 represented 72.5 per cent of the total rated capacity.

Part of this 27.5 per cent margin, not in use at the time of the peak represents hydro capacity unavailable at the time (December) because of insufficient stream flow. Another part consists of necessary reserve against outage and breakdown. With the employment of large units and the practice of providing for the largest unit being out of service at the time of peak, this reserve cannot wisely be allowed to fall below 10 to 20 per cent and is much higher in some systems because of the character of the service.

Still another part of the 27.5 per cent margin above the peak demand represents provision for system growth. Bearing in mind that the normal growth in load over a considerable period averaged ten per cent per year it was necessary to anticipate the increase. Many companies did this by the installation of larger machines in order to take advantage of lower unit investment costs and higher efficiency. Thus, while the load grows gradually, the capacity grows by sudden steps, and for many months after each new installation is made the utility has an increased margin of unused capacity. The average percentage in reserve at time of peak for fifty-three large companies was 27.9 which checks very closely with the 27.5 per cent previously mentioned for the whole country.

Obviously, the author's studies lead up to an answer to the question: Did capacity exceed practical requirements in 1929? While the evidence does not permit of a clear-cut answer, which must be modified for individual systems, he ventures the opinion that while there was some excess capacity, in certain localities, and there was doubtless some excess forward building, this excess was relatively small. On the whole, it consisted chiefly of obsolete plants and equipment (included in the total figures) which were retained through unwillingness to write off the investment. The general conclusions are that there was no evidence of a progressive inflation of capacity during the period from 1900 to 1929. The provision for system growth left a reserve margin greater than the chance of breakdowns alone would justify. While in 1929 the amount of this provision for growth was sufficient to permit a substantial increase in output, over and above the actual demands of the country's industries, nevertheless, it was not sufficient to furnish all the power that the industries would have needed had they operated at 100 per cent capacity instead of at about 83 per cent. In other words, the central station capacity in 1929 was somewhat below the full capacity requirements of the mines and factories dependent on central-station power.

This study and analysis, which includes many statistics contained in the appendix, provides an exceptionally lucid picture of the situation as of 1929. What of 1934? Little additional capacity, especially in steam plants, has been added during the past three years and much of the obsolete equipment mentioned by the author as being carried through unwillingness to write off, still obtains, although five years older. In fact, the intervening period has actually added to the obsolete equipment. While the load gradually declined to 79 per cent of the 1929–1930 index in March 1933 it has since been steadily recovering and is now back to the high mark of January 1931 and, when adjusted for seasonal variation, is not far behind the index for 1929–1930.—*Editor*.

[1] By E. G. Nourse and Associates.

Looking down the rows of pulverizing mills

Remodelled Lincoln Station of Boston Elevated Railway Co.

By W. J. VOGEL
Combustion Engineering Company, Inc.

In remodelling the Lincoln Station four batteries of old boilers were replaced by four new steam-generating units each with a capacity of 176,000 lb of steam per hour at 450 lb pressure and 750 F. With water walls backed by tile and direct firing of pulverized coal the heat liberation at maximum rating is 26,900 Btu per cubic foot of furnace volume. The boiler walls are of special design. Roller type mills are employed and variation in steam demand is met by controlling the speed of the mill and the mill blower. Steam is supplied to a 35,000 kw turbine-generator.

THE Lincoln Power Station of the Boston Elevated Railway Company is one of the oldest power stations on the eastern seaboard, the first unit having been started in 1900. The original equipment, consisting of twenty-five low-head, long-drum, sectional header boilers set in batteries and vertical compound engines, direct connected to 2700 kw, 3-phase, 25-cycle, 575-volt generators, has been replaced by modern boiler units and steam turbines.

Ten battery settings comprised the original boiler room. Above the center bay is a 5000-ton coal bunker supported by the building columns from which the boilers were also suspended. Four batteries were removed, two in each bay, for the four new boiler units. The new units, being of greater weight, necessitated columns of stronger section. Aside from new steel for suspending the new units no other building changes were necessary. The old batteries, containing two 500 hp, four 443 hp and four 600 hp boilers, operated at 175 lb pressure and 50 deg superheat. Each of the new boilers is 1140 hp, designed to operate at 450 lb with a range in capacity from 25,000 to 176,000 lb of steam an hour from and at 212 deg.

The boilers are of the Walsh-Weidner sectional-header type, 14 tubes high, 30 tubes wide, with tubes 22 ft 0 in. long. An interdeck space above the fourth row of tubes is provided for an Elesco superheater of 3300 sq ft heating surface. For the capacities noted above the final steam temperature ranges from 630 to 750 F.

The furnace has a volume of 7700 cu ft. The two side walls and the rear wall are completely covered with C-E 4-in. fin tubes set on $6^1/_8$ in. centers. A plain-tube water screen extends across the furnace bottom. Riser tubes from the floor screen enter the furnace and, passing up the inside face of the front refractory wall, serve to shade this wall from radiant heat. Two burners are located in the front wall. The ash hopper is of V-type construction and has ample volume.

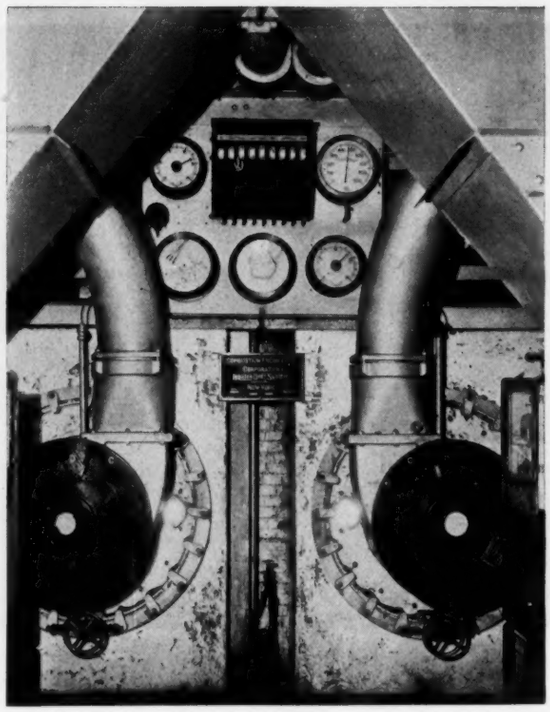
Furnace side wall tubes enter vertically into the under-

side of the upper square headers located adjacent to the boiler drop leg sections. From the top sides of these headers riser tubes pass up and through the refractory side walls into short headers. These headers are, in turn, connected by tubes across the boiler roof to the drum steam space.

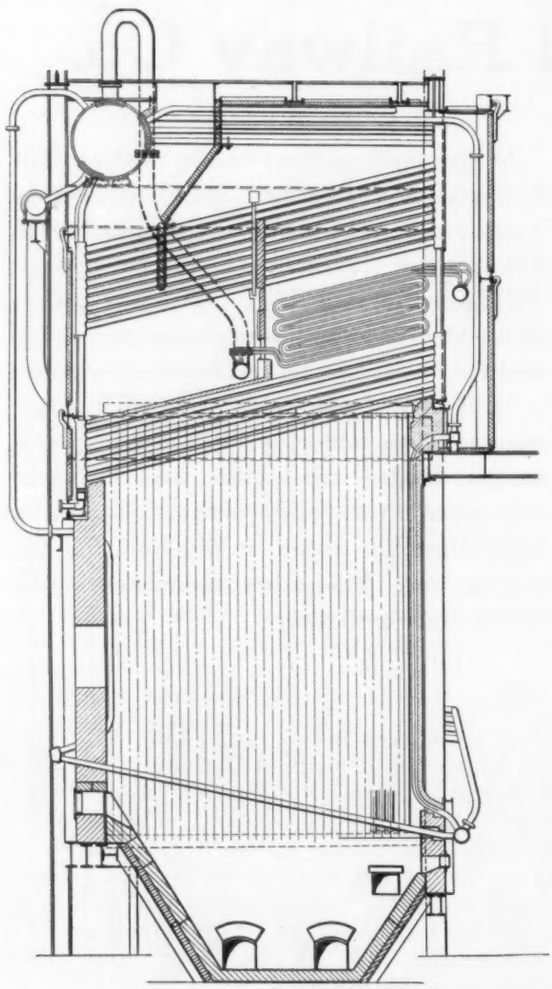
The boiler side walls involve a construction of special design. They are 12-in. thick and are of special tile, the central portion of each tile being notched. As the tile are placed they completely enclose the riser tubes. Sufficient annular space is provided about the tubes to permit free expansion of both tubes and walls. To the outside vertical buckstays are connected several horizontal rows of cast-iron seat angles. These divide the wall into sections and support the refractory load. This wall is light in weight and economical to construct. The riser tubes are completely hidden and air infiltration through the walls is reduced to a minimum, as the outside is covered with a 3-in. layer of plastic.

A novel feature of this installation is that the direct-fired method of burning pulverized fuel is used with roller mills. There are two mills to each boiler, each mill supplying pulverized coal to one horizontal forced-draft round burner.

The mills are the standard Raymond design with three rollers automatically lubricated with oil, and having a maximum capacity of four tons per hour of Pocahontas coal. They are located in the basement of the boiler room but the mill blowers and mill feeders are placed on the operating floor at the level of the burners. Oil for mill lubrication is by gravity flow from an overhead supply to permit continuous operation.



The instrument panel is located on the boiler front just above and between the burners



Section through boiler setting

Variation in the demand for steam is controlled entirely by the regulation of the coal pulverizing and burning equipment. Increased demand for steam is met by increasing the rate of milling and delivery of pulverized coal to the boiler furnaces. The increased rate of milling is obtained by speeding up the mill and mill blower. Both mill and blower are driven by direct-connected slip ring motors. With the Raymond roller mill the rate of pulverization varies approximately as the cube of the speed so that a small variation in the speed gives a comparatively large variation in the output of the mill without materially changing the fineness of the coal. Generally a variation in speed from 70 to 100 per cent is accompanied with a variation in the mill output from 33 to 100 per cent.

For any rate of milling a uniform supply of coal is delivered by the mill. This is accomplished by maintaining within limits a practically constant thickness of the coal bed in the mill base. This fuel depth produces a predetermined pressure drop in the mill air flow. If the fuel depth increases due to over supply from the feeder the pressure drop is increased to a point where, operating through a pneumatic control, the feeder motor circuit is opened and stops the coal feed. As soon as the pressure drop decreases the feeder motor circuit is again closed and coal is again fed to the mill. The mill feeder is driven by a constant speed motor. Its operation is therefore intermittent. The period of time elapsing between feeder motor operation and the length of time of its operation is thus dependent upon the mill demand.

The air passing through the mill is the primary air

Rear wall of boiler showing air-tight construction

used for combustion and therefore the amount of primary air is regulated by the mill blower control. Drying of the coal is done directly in the mill by means of preheated air bled from the main preheated air supply.

Secondary air for combustion is supplied by one fan per boiler. Air for combustion is preheated to from 443 F at 50,000 lb evaporation to 572 F at 175,000 lb evaporation by passing through a Ljungstrom air preheater located immediately above the boiler roof.

The flue gases after leaving the preheater at 200 F at 50,000 lb rating to 299 F at 175,000 lb rating pass through a Cottrell electrical precipitator to induced-draft fans and the stack.

At the low load of 25,000 lb of steam the furnace liberation is 3820 Btu per cu ft. At the peak load of 176,000 lb of steam the liberation is 26,900 Btu per cu ft of furnace volume. To date, each unit has freely worked through the specified range of capacity and has operated above 184,000 lb per hour without being extended.

The turbine-generator is an improved combination impulse and reaction design rated at 35,000 kw, the condenser for which is of the two-pass type with cast-iron shell and designed for 29 in. vacuum.

H. A. Barre, Chief Engineer of the Southern California Edison Company died suddenly on June 28 from a cerebral hemorrhage. He was 59 years old. A graduate of the University of California in 1897, his whole engineering career was concerned with the design operation and management of power plants. After several years in consulting practice, he joined the Electric Bond & Share Company where he became engaged in appraisal work. In 1911 he became identified with hydro projects on the Pacific Coast as mechanical and electrical engineer of the Pacific Light & Power Corporation.

1300-lb Boilers Show High Availability

Further proof that the availability factors of high-pressure installations, when properly designed, are as good as those of moderate pressure, is to be found in the record of Boiler Room No. 3 at Lakeside Station of the Milwaukee Electric Railway and Light Co. This boiler room contains four units operating at 1300-lb steam pressure and 750 F steam temperature. The first unit was installed in 1926 and the others in 1929–1930. Disregarding the first unit, which because of the superheat and reheat arrangement is slightly less flexible, the average availability for the three later units for the year 1933 was 98.1 per cent. The number of times these boilers were banked during the year were, respectively, 224, 230 and 233, and of the time the units were actually out of service only about 60 per cent was chargeable to maintenance.

These units are of the Combustion Engineering bent-tube type, rated at 300,000 lb of steam per hour. They are fitted with radiant type superheaters and fired with a bin-and-feeder pulverized coal system in which the coal is dried in the mills by waste flue gases.

Navy Studying Fuel Oil

As the demand for gasoline has increased and control of crude production became more evident, the supply of boiler oil has been derived more and more from residuals of the cracking process. Moreover, as the crudes come from many fields the characteristics of these residuals is not uniform.

It became apparent a few years ago that some of these oils when burned under naval boilers resulted in clogging of the heaters and gave evidence of other undesirable qualities. Therefore, with a view to determining whether cracked residuals make satisfactory naval fuel oil and, if some do, how the undesirable ones could be eliminated, the Bureau of Engineering appointed a board of officers to make a preliminary study. The report of this board resulted in the decision to institute a thorough investigation of the subject by tests at three separate research laboratories maintained by the Navy, namely, the Naval Boiler Laboratory at Philadelphia, the Naval Research Laboratory at Anacostia and the Engineering Experiment Station at Annapolis. At the first of these, critical burning tests were undertaken; chemical research was instituted at the second; and heating tests on cracked residual fuel oils were made at the third. The work is still in progress[1] but the results so far are such as to form the basis for revised specifications.

Heretofore, the specifications covered three grades, namely, Bunker *A*, Bunker *B* and Bunker *C*. The last is most generally available but with its present maximum viscosity is not suitable for use in many Naval vessels. Bunker *A* is no longer available in large quantities while Bunker *B* is. The new specifications cover a compromise fuel oil to replace these three previously designated grades.

[1] For an exhaustive review of this work see the Journal of the American Society of Naval Engineers, May 1934.

The Logical Way to Control Treatments of Boiler Feedwater

By CYRUS W. RICE

Water Chemist and Engineer, Pittsburgh

The author shows that analysis of raw water alone is not sufficient, but that complete analysis of thoroughly representative samples of feedwater, boiler concentrates, condensates and scale deposits, with proper correlation of the results are necessary to intelligent conditioning of boiler feedwaters. Moreover, collection of the samples is most important and laboratory analysis is to be preferred to plant analysis because of greater accuracy.

RAIN, because of its solvent properties, gathers objectionable constituents to boiler feedwaters in its travels through or over the ground to the different sources where it is gathered together for steam-generating purposes. The natural constituents in the ground which make up most of these are:

Calcium bicarbonate
Calcium carbonate (chalk)
Calcium sulphate (gypsum)
Calcium silicate
Calcium chloride
Magnesium bicarbonate
Magnesium carbonate
Magnesium sulphate (epsom salts)
Magnesium silicate
Magnesium chloride
Sodium bicarbonate
Sodium chloride (salt)
Sodium sulphate (Glaubers salt)
Sodium silicate (water glass)
Carbonic acid
Oxygen
Organic matters

Other pick-ups through industrial and mine water waste are sulphuric acid, iron sulphate and many complex organic compounds. Some manufacturing processes, also, add to the complicated messes so common to most boiler feedwater supplies. The continuity and safety of every boiler operation is jeopardized by water supplies carrying these materials. I refer in particular to such feedwaters that are either untreated or incorrectly treated.

The impurities dreaded the most in these pick-ups are those which are destructive to boiler metals. Magnesium chloride, sulphuric acid, iron sulphate, carbonic acid and oxygen are most active in this capacity.

While magnesium chloride may be considered neutral in every way in the feedwater heating and feeding equipments, it decomposes under boiler pressures and temperatures and in the presence of water and in contact with iron produces hydrochloric acid. Some authorities claim that magnesium sulphate and calcium sulphate break down under similar conditions. The chemical reactions within the boilers which bring about the mentioned decompositions are as follows:

$$MgCl_2 + H_2O = MgO + 2HCl$$
$$MgO + H_2O = Mg(OH)_2$$
$$MgSO_4 + H_2O = MgO + H_2SO_4$$
$$MgO + H_2O = Mg(OH)_2$$
$$CaSO_4 + H_2O = CaO + H_2SO_4$$
$$CaO + H_2O = Ca(OH)_2$$

The most active of the artificial contaminations in causing metal losses are sulphuric acid and iron sulphate.

Water supplies from swampy sections, because of their organic acid content, have shortened the life of some boilers, but this occurrence is very infrequent. Of the remaining causes for metal losses in boilers, oxygen and carbonic acid are by far the most extensive in their attack and the most expensive.

Probably the most serious type of boiler failures today, because of the hidden unforeseen manner in which it occurs in the under-water joints of a steam boiler, is the kind described today under the term of "caustic embrittlement." This is usually caused by feedwaters containing free sodas from either natural sources or from water softeners in which the sulphate to alkalinity ratio is less than the ratio recommended by the A.S.M.E. The natural sources of such water supplies which have caused failures of the kind mentioned are to be found in practically every section of the United States and are almost totally obtained from wells.

The less important materials in the group given are those which cause adherent scale deposits of a type that prevent water from reaching the metal-evaporating surfaces. We say "less important" because they have no appreciable effect on metal losses and are easy to remove where proper control is exercised over the chemical conditioning of boiler feedwaters. The materials in nature that are outstanding in this connection are calcium sulphate and calcium silicate. Of these, calcium sulphate, which is generally known as "plaster of paris," is the common constituent of most hard scale deposits, while calcium silicate is the more troublesome, because of the porcelain-like deposits it causes and greater treating difficulties that are experienced in preventing its formation over the evaporating surfaces within boilers.

The least important of the materials contained in feedwaters are calcium and magnesium carbonate and bicarbonate and soluble chlorides and sodium sulphate. The first-named deposit more or less in the feedwater heating and feeding equipments and economizers in solid formations and as sludge and solid deposits in the boilers. The sulphates and chlorides of sodium are objectionable, because of their influence in increasing the

tendency of impurities within the boilers to carry over with the steam.

In any set-up, regardless of the water or operating conditions in use, the most logical procedure, and the one that will give the most reliable facts for correcting any and all undesirable factors in any work under advisement is to make a thorough survey of the whole feedwater and steam situation. This should include a complete mineral analysis of the raw make-up water collected after the heater, the boiler concentrates, boiler-tube deposits, condensed steam and condensate returns.

Exhibit 1 represents a simple survey covering a plant in Pennsylvania in which the one requirement was to reduce the cost of treating. Here they were using a compound costing approximately $1000 per year.

EXHIBIT 1

	Raw water	Blowdown water
	(Grains per U. S. Gallon)	
Temporary hardness ($CaCO_3$)	7.89	...
Permanent hardness ($CaCO_3$)	1.55	...
Pht. alkalinity ($CaCO_3$)	...	11.7
M. O. alkalinity ($CaCO_3$)	...	13.8
Total dissolved solids	10.45	24.76
Suspended matter	.08	1.37
Calcium bicarbonate ($CaCO_3$)	5.27	nil
Calcium carbonate ($CaCO_3$)	nil	1.19
Magnesium bicarbonate ($MgCO_3$)	2.20	nil
Magnesium carbonate ($MgCO_3$)	nil	1.04
Sodium bicarbonate ($NaHCO_3$)	nil	nil
Sodium carbonate (Na_2CO_3)	nil	1.44
Sodium hydroxide (NaOH)	nil	8.00
Calcium sulphate ($CaSO_4$)	nil	nil
Magnesium sulphate ($MgSO_4$)	1.86	nil
Sodium sulphate (Na_2SO_4)	nil	3.07
Calcium chloride ($CaCl_2$)	nil	nil
Magnesium chloride ($MgCl_2$)	nil	nil
Sodium chloride (NaCl)	.70	4.80
Iron and alumina (R_2O_3)	.10	.16
Silica (SiO_2)	.32	5.10

The compound used contained,

Water	75.2 per cent
Iron and aluminum oxide	0.37 per cent
Sodium chloride	0.27 per cent
Sodium carbonate	0.98 per cent
Sodium hydroxide	2.75 per cent
Sodium silicate	19.75 per cent

This is diluted commercial water glass.

The boiler, after two years with this treatment, was found to be badly scaled. The incorrectly treated condition of the boiler water is clearly indicated by the 1.19 grains per gallon calcium carbonate and 1.04 grains magnesium carbonate which remain in the boiler concentrates. As this was a low-pressure installation a treatment of soda ash was substituted for the compound. This was added in quantities to maintain an average methyl orange alkalinity of 30 grains. The removal of considerable quantities of old scale resulted. These soda concentrations required the use of 5.5 lb of soda ash daily at a cost of 11 cents per day or about $40.00 per year, as against the mentioned figure of $1000.00.

Exhibit 2 is the result of a survey covering a plant in Massachusetts whose boilers were badly scaled. This is reflected in the 90.4 per cent calcium sulphate which was contained in the first sample of tube scale from the plant. The undertreated condition is further shown by comparing the sulphate to chloride relation in the raw water of 2.66 with the same relation in the boiler concentrates of 1.04. By way of explanation let it be said here that if a feedwater is correctly treated the sulphates divided by the chlorides in the boiler concentrates are equal to or greater than the sulphates divided by the chlorides in the raw water. In this survey, it is less than one-half, proving that sulphates as calcium sulphate were being deposited within the boilers. Another interesting fact brought out in the analysis, and which has a bearing on the treatment, is the high concentration or turnovers in the boiler. This is determined in all cases by dividing the chlorides in the feedwater into the chlorides contained in the boiler concentrates. In this particular Exhibit this approximated 100 times, which is far too excessive because such concentration accelerates scale depositions.

EXHIBIT 2

	Raw water	Heater discharge	Condensate returns	Condensed steam	Boiler blowdown
	(Grains per U. S. Gal.)				
Temporary hardness ($CaCO_3$)	1.28	..	..	..	....
Permanent hardness ($CaCO_3$)	2.24	..	..	..	....
Pht. alkalinity ($CaCO_3$)	..	0	0	0.46	8.1
M.O. alkalinity ($CaCO_3$)	..	0.81	0.47	1.16	12.7
Total dissolved solids	5.22	..	1.99	1.98	196.0
Suspended matter	0.12	0.19	0.19	0.33	0.12
Calcium bicarbonate ($CaCO_3$)	1.28	..	..	..	....
Magnesium bicarbonate ($MgCO_3$)	nil	..	..	..	....
Calcium sulphate ($CaSO_4$)	1.99	..	..	..	....
Magnesium sulphate ($MgSO_4$)	0.54	..	..	..	....
Sodium sulphate (Na_2SO_4)	nil	..	..	..	74.4
Calcium chloride ($CaCl_2$)	nil	..	..	..	....
Magnesium chloride ($MgCl_2$)	0.31	..	..	..	....
Sodium chloride (NaCl)	0.83	0.70	0.40	0.30	72.2
Iron and alumina (R_2O_3)	0.05	..	..	..	....
Silica (SiO_2)	0.22	..	..	..	....
Permanganate consumed ($KMnO_4$)	0.26	..	..	..	....
Oil	..	trace	trace	..	....
Sodium sulphate per grain of salt	2.66	..	..	..	1.04
Ratio sodium sulphate to alkalinity as $CaCO_3$	..	..	..	..	5.9
pH	8.1	7.3	8.1	9.3	10.0

	Tube Scale	*Cylinder Oil*	*Soda Ash*
Silica	7.43%	Saponifiable matter 0.97%	Sodium carbonate 93.2%
Iron oxide	1.92%		
Calcium sulphate	90.4%		

The first move in this case was to reduce the total boiler concentrations. This was done by increasing the blowdowns until the salt test was about one-half of the former amount. The soda ash treatment which was used here was next increased with a resulting change in the M.O. alkalinity from 12.0 to near 25.0 grains per gallon. Both changes had a material effect in decreasing the calcium sulphate content in a period of four months from 90.4 to 1.5 per cent. The monthly analysis of the tube deposits tells its own story as follows:

	Calcium sulphate
June 6	90.4 per cent
July 25	31.9 per cent
Aug. 27	17.5 per cent
Sept. 28	1.5 per cent

All of the above analyses represent composite samples of deposits from fire-exposed tubes for the particular month in which they were collected.

To prevent undue tube losses and internal boiler disturbances resulting from the sudden removal of too much old scale on deposit all treatments in such cases should be gradually increased.

At this plant, largely because of the treatment and various uses to which the steam was being applied, special attention was given to checking the corrosive properties of the feedwater and checking the quality of the steam for purity.

In all cases where old scale is to be removed, particular attention must be paid to the effect the disintegration of old scale has on the steam quality. Where the daily plant tests of bleeder samples of condensed steam indicate undue carryovers the blowdowns should be either increased or the treatment reduced or changed.

Exhibit 3 is the case of a plant in the State of Washington. Here the treating was done with another sodium silicate compound with the composition indicated by the analysis. The tube scale in the initial survey contained objectionable quantities both of silica and calcium sulphate.

The sulphate-to-alkalinity ratio was also totally out of line. The water in use for boiler feed was from wells and was better than average quality. A treatment of

EXHIBIT 3

		No. 1 Well water	No. 2 Well water	Water from concrete tank	Heater discharge	Blowdown water	Retort coil condensate	Retort room pump condensate
		(Grains per U. S. Gallon)						
Temporary hardness	($CaCO_3$)	4.71	3.90	3.7	..	...	...	..
Permanent hardness	($CaCO_3$)	..	1.60	1.2	..	...	...	..
Free soda	(Na_2CO_3)	.70	...	..	..	...	...	..
Pht. alkalinity	($CaCO_3$)	..	...	..	nil	15.9	nil	nil
M.O. alkalinity	($CaCO_3$)	..	...	..	2.9	16.3	.58	.46
Total dissolved solids		8.82	10.37	6.65	..	...	...	..
Suspended matter		.12	.13	.24	.18	...	.18	2.25
Calcium bicarbonate	($CaCO_3$)	2.07	1.73	1.69	..	...	...	..
Magnesium bicarbonate	($MgCO_3$)	2.24	1.82	1.68	..	...	...	..
Sodium bicarbonate	($NaHCO_3$)	1.10	nil	nil	..	...	...	..
Calcium sulphate	($CaSO_4$)	nil	nil	nil	..	...	...	..
Magnesium sulphate	($MgSO_4$)	nil	.65	.76	..	...	...	..
Sodium sulphate	(Na_2SO_4)	.89	nil	nil	..	6.25	...	..
Calcium chloride	($CaCl_2$)	nil	nil	nil	..	...	...	..
Magnesium chloride	($MgCl_2$)	nil	.95	.60	..	...	...	..
Sodium chloride	($NaCl$)	1.20	3.70	.50	3.5	25.3	.70	.30
Silica	(SiO_2)	1.25	1.43	1.41	..	...	...	..
Iron and alumina	(R_2O_3)	.07	.09	.09	..	...	...	..
Oil		..	...	..	.83	...	.61	4.63
Relation of sodium sulphate to alkalinity as calcium carbonate		..	...	..	..	.39	...	..
Sodium sulphate per grain sodium chloride		.74	...	..	..	.25	...	..

Sample Marked: *Tube Scale*

Silica	(SiO_2)	30.9%
Iron oxide	(Fe_2O_3)	6.8%
Calcium sulphate	($CaSO_4$)	20.3%

Cylinder Oil

Saponifiable matter .36%

Boiler Compound

Silica	(SiO_2)	16.75%
Sodium oxide	(Na_2O)	14.15%
Water	(H_2O)	51.70%

soda ash, disodium phosphate and sodium sulphate was applied here with excellent results. This is reflected again in the periodic analysis of tube scale samples from the plant. These were:

	Silica	Calcium sulphate
Initial	30.9%	20.3%
July 13, 1931	25.1%	6.4%
Nov. 3, 1931	23.3%	.5%
July 25, 1932	21.1%	.5%

Exhibit 4, a water from South America, has considerable interest.

EXHIBIT 4

	Raw water	Feed-water	Boiler blowdown, under-treated	Boiler blowdown, treatment effective
	(Data is in grains per U. S. Gallon)			
Total dissolved solids	117.0	24.0	1342.0	1371.0
Suspended solids	0.3	trace	3.0	80.0
Silica (SiO_2)	0.6	0.1	5.0	6.5
Temporary hardness ($CaCO_3$)	2.4	0.5	0.5	0.5
Permanent hardness ($CaCO_3$)	19.0	3.8	48.8	0
Calcium bicarbonate ($CaCO_3$)	2.4	0.5	0.5	0
Calcium carbonate ($CaCO_3$)	0	0	0	0.5
Magnesium bicarbonate ($MgCO_3$)	0	0	0	0
Sodium carbonate (Na_2CO_3)	0	0	0	25.1
Sodium hydroxide ($NaOH$)	0	0	0	5.5
Calcium sulphate ($CaSO_4$)	2.5	0.5	12.6	0
Magnesium sulphate ($MgSO_4$)	7.5	1.5	46.2	0
Sodium sulphate (Na_2SO_4)	0	0	12.4	140.0
Magnesium chloride ($MgCl_2$)	10.9	2.2	0	0
Sodium chloride ($NaCl$)	93.0	18.6	1270.0	1200.0
Oil	....	0.6	....	....
Ratio sodium sulphate to alkalinity as calcium carbonate	....	..	16.0	4.3
Ratio SO_3:Cl	0.102	..	0.058	0.109
Ratio SiO_2:Cl	0.0095	..	0.0065	0.0090

The raw or make-up is highly contaminated and especially objectionable because of the large amount of magnesium chloride and sulphate it contains and corrosive effects these have in improperly or under-treated concentrates. This was pronounced in this case, as can be seen in the analyses of the boiler blowdown water and excessive corrosion with which the plant was troubled. The treatment here was trisodium phosphate and soda ash.

Experiments in the laboratory with the water under the same concentrations and boiler pressures as existed at the plant indicated trisodium phosphate to be unnecessary and costly. The final treatment developed in the laboratory for the particular water was a combination of 2.5 lb soda ash and 1 ounce sodium aluminate per 1000 gallons make-up and maintenance of 25 to 30 grains M.O. alkalinity with a salt concentration limit of 600 grains in place of 1200. This, with the natural sulphates present in the water, gave a sulphate to carbonate ratio of better than 2 to 1, which met the A.S.M.E. requirements for the existing steam pressures and at the same time permitted of better steam qualities.

A comparison here of the sulphate to chloride and silica to chloride ratios in the raw water with similar ratios in the boiler concentrates clearly indicated the under-treated conditions which existed. Another comparison of these same ratios in the raw water with those in the correctly treated boiler concentrates shows the former under-treated conditions to have been totally eliminated.

The complete analyses of representative samples of boiler tube scale also furnish evidence of the effect of treatments in eliminating the unsatisfactory conditions.

EXHIBIT 5

	Analyses of Boiler Deposits					
	Sulphate Scale		Silica Scale		Iron Scale	
	First analysis at start of service	Last analysis	First analysis at start of service	Last analysis	First analysis at start of service	Last analysis
Silica SiO_2	8.0%	12.8%	54.9%	21.6%	6.3%	8.41%
Iron Fe	1.0	9.8	5.2	1.6	50.6	8.00
Calcium sulphate $CaSO_4$	82.5	0.5	1.5	0.43	0.62	0.63

Exhibit 5 is an example of several scale analyses, each of which shows all unsatisfactory conditions to have been corrected. To obtain facts that are definitely conclusive and absolutely reliable for continued control work, especially for high boiler pressures and ratings, periodic analyses should be made of composited representative samples. These should always comprise make-up, blowdown water, scale from fire-exposed tubes, samples of condensed steam and condensate returns. If a water softener is in use, the analyses of samples from this should also be made at definite, regular periods.

The early work of the organization with which the writer is connected, provided for more tests in the field, but further experience and comparison of the results between the plant and laboratory, showed many of these tests to be unreliable, therefore the plant was limited to such testing as was found it could conveniently do and turned over to the laboratory the work which required greater accuracy.

During the past, crude methods were employed for sulphate determinations and other practices equally as faulty were used for checking the influence of the various treatments, but the results of more than twenty years of experience in this special work have taught the value of

accuracy. This is found to be just as important in the analytical work of the laboratory as it is in the collection of the samples. Under the circumstances all samples must be thoroughly representative. The selection of these, therefore, has been a separate study in itself, because the value of any analysis is totally dependent upon this, if reliable facts for control work are to be obtained. The invariable policy in this connection is to gather composited bleeder samples over the period of a week. Where a survey of a feedwater situation is under way for a particular plant, all samples are collected in this way and over the same dates.

In that the treatment of boiler feedwaters involves many conditions, such as the removal of old deposits, prevention of new deposits, the sulphate to alkalinity relations, steam qualities, operation of water softeners, the quality of the steam and effect it may have on certain processes, acceleration or prevention of gas corrosion in any one or more of the steam-generating or accessory equipments, the lowering of treating costs, etc., it is extremely important that analyses be made of every source that will give the pertinent facts for fully correcting the conditions under advisement with the least operating disturbances.

The analysis alone of the raw or feedwater itself has no special significance and should, therefore, never be used as a means for determining the kind of a treatment for conditioning purposes. This can only be found definitely after the facts given by the various analyses are correlated and results of the whole are interpreted correctly. Not only is it necessary to determine the initial treatment in this way but also all future control work because of the changes in the mineral composition of feedwaters and changes in the condensate returns and boiler ratings which require definite periodic checking both at the plant and in the laboratory if all unsatisfactory water and steam conditions are to be maintained at the practical minimum.

For such purposes, many treatments are available, among which are,

1. Sodium carbonate (soda ash)
2. Sodium bicarbonate
3. Sodium hydroxide (caustic soda)
4. Trisodium phosphate
5. Disodium phosphate
6. Monosodium phosphate
7. Meta sodium phosphate
8. Calcium hydroxide (hydrated lime)
9. Calcium oxide (chemical lime)
10. Colloids

Of these treatments, *No. 1* is the least expensive and has the most universal application principally for low-pressure boilers and lime-soda softener operations. *No. 2* proves useful where the waters cause feed line deposits. Its application is totally for internal treatment through feed lines and heaters. It should be avoided where corrosion proves troublesome. *No. 3* is employed for controlling the pH in feedwaters and boiler concentrates mainly in conjunction with treatments 6 and 7. *Nos. 4, 5, 6 and 7* are internal treatments only and because of their common tendency to cause feed line and pump deposits may have to be introduced directly into the boilers. *Nos. 8 and 9* are for external use although there are occasions where small additions of lime to the boiler concentrates have proved effective in arresting some troublesome cases of gas corrosion. Under such circumstances extreme care and close checking are necessary. *No. 10.* These agents prove useful in many cases where there is a tendency for chemical precipitates to cement or grow together under the best soda treatments. They also prove useful in preventing feed line, open or closed heater and pump deposits.

Another common external method for softening feedwater is to pass it through beds of zeolite. This exchanges the soda contained in the zeolite for the dissolved calcium and magnesium salts in the raw waters as these filter through the beds, converting the bicarbonates of these bases to sodium bicarbonate, and sulphates and chlorides to sodium sulphates and chlorides. Where water and operating conditions do not allow for the maintenance of the A.S.M.E. recommendations for sulphate relations, it is advisable to supplement the mentioned list of chemicals with sodium sulphate, sodium bisulphate or sulphuric acid, the same depending upon the analysis of the water to be treated, amount of water and operating conditions to be met. In any case, the decision as to what to do in these matters should be given a careful analysis by competent feedwater chemists.

The elimination of free oxygen and carbonic acid mentioned in the early part of this article is usually effected through proper control of the temperatures and pressures of the feedwater before it enters the boilers. There are occasions when the facilities in use are inadequate and impossible for such regulations. Where CO_2 is the principal constituent and corrosion occurs, the mentioned caustics are either employed or some of the boiler blowdown water is recirculated with the feedwater. Under similar circumstances, if oxygen is not excessive, chemical treatments can be used for absorbing it or for making the metals passive to its actions. There are various materials available for this purpose, among which are chromates, tannic acid and sodium sulphite.

When the above discussion is summarized, the practice of treating under definite scientific control clearly indicates:

1. That the intelligent conditioning of boiler feedwaters can best be accomplished where the facts for controlling this are accurate and dependable.
2. That complete mineral analyses of thoroughly representative samples of feedwater, boiler concentrates, condensates and scale deposits and proper correlation of the results are the most satisfactory means by which these facts can be obtained.
3. That the analysis of a raw water alone does not give enough facts for this purpose.
4. That operating and water conditions are so widely different that it is not possible to use one treatment or "cure-all" to meet every situation.
5. That incorrect treatments will cause corrosion within the boilers and addition of corrosive gases to the steam with their destructive influences on turbines, condensate return pipes, etc.
6. That such facts obtained through complete analyses and factors derived from them give indisputable evidence as to whether—
   a. The sulphate relations recommended by the A.S.M.E. are actually being maintained;
   b. The treatments in use are effective in preventing scale and known to be so under steaming conditions;
   c. The treatment in use or total concentrations are not causing any undue carry-overs into the steam;
   d. Corrosion is or is not taking place.

Experiences with Boiler Feed Pumps

This statement of a subcommittee of the Prime Movers Committee, Edison Electric Institute, represents a digest of reports by twenty operating companies in response to a list of fourteen questions submitted covering specific items in boiler feed pump operation. Sixteen of the stations reporting were in the medium pressure class and four in the 1200–1400 lb class. The complete report is contained in Publication No. 33, entitled "Condensers, Feedwater Heaters, Evaporators and Boiler Feed Pumps," dated June 1934.

THE designs for boiler feed pumps for pressures up to about 500 lb per sq in. have been developed to a point where operating difficulties are of a minor nature. Bronze pump parts give long service and usually show little wear even after several years' service. Special alloys have been tried out but it does not appear that their use is warranted except possibly for such places as hydraulic balance drums and packing sleeves.

High Pressure Boiler Feed Pumps

Boiler feed pumps for high pressure (1200–1600 lb), however, have in the past few years passed through a period of development where almost every conceivable trouble has been experienced.

Cast steel pump casings have developed serious leakage and in some instances such defects have not shown up for over a year after the pump was put in service. Redesign of casings to give shapes suitable for making sound steel castings or the adoption of forged steel castings has been the solution for these troubles.

Wearing rings and shaft sleeves of bronze have proved unsatisfactory and have been replaced with stainless steel rings and stainless steel or nitralloy sleeves which are standing up very well.

Pump shafts have broken repeatedly and have been replaced with much larger shafts, especially designed to eliminate points of concentrated stress.

Leakage past balancing drums which increases very slowly in the moderate pressure pumps increases rapidly in high pressure pumps of the earlier design. The balancing devices have been radically modified and carried out in alloys, so that pumps of the latest design operate for long periods without trouble.

The experiences of one company reporting is especially interesting. They have installed three different sets of high pressure boiler feed pumps for the same plant. Whereas the first two sets were entirely unsatisfactory, each set has shown distinct improvements over the previous set and the third set operates with the same reliability and with no more maintenance troubles than the low pressure pumps in the same station.

It can, therefore, be stated that reliable, efficient and satisfactory high pressure pumps are now available. The development period has been passed through, many forms of trouble have been experienced and solutions found.

While the operating data presented indicates that the high pressure pumps fall off in capacity and efficiency with hours of service more rapidly than low pressure pumps, overhauling re-establishes the original characteristics. It is believed that the pumps of the latest design can be maintained in nearly their "when new" condition with reasonable maintenance expense.

Shaft Packing

Lubricated, braided asbestos packings and metallic packings are both being used successfully while flax packings have been shown to score the packing sleeves. The care exercised in fitting and adjusting the packing determine to a large extent the life obtained.

Lubrication

Lack of adequate lubrication for the thrust bearings when starting up has caused many high pressure pump outages. By flooding the thrust bearing with a pumped supply of oil, this trouble has been practically eliminated.

Parallel and Low Load Operation

Parallel operation has been satisfactory, at all loads, where the pumps have drooping head-capacity characteristics from no load to full load. However, many pumps do not have this shape of characteristic and in such cases hunting occurs if the pumps are operated in parallel at the unstable points on their curves.

The same shape of characteristic that permits satisfactory parallel operation (i.e., drooping from 0 to full load) permits stable operation at light load. When the load is so low that the feedwater regulators may at times stop the flow altogether, a recirculating line is used if the packing leak-off is not sufficient to keep the pumps cool.

Differential Pressure

Operating experience pretty definitely shows the economy of variable pressure differential between pump discharge and boiler drum pressure with variation in load. This is sometimes accomplished by automatic control and sometimes by manual control of pump speed. Variable differential not only saves boiler feed pump power but reduces maintenance on feedwater regulator valves, pressure regulator valves if used and on the boiler feed pump itself.

Variable speed drives for boiler feed pumps are general practice in spite of the higher first cost and maintenance on variable speed a-c motors. A less costly, more reliable and more efficient variable speed a-c motor is urgently needed. The wound rotor induction motor leaves much to be desired.

High Temperature Boiler Feedwater

The pumping of high temperature water requires more power than for low temperature water.

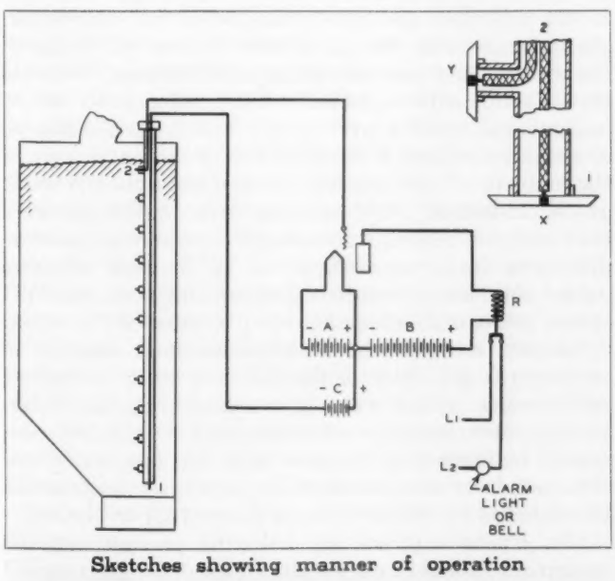
High temperature water, or the greater fluctuation in temperature of water from high temperature heaters, seems to be conducive to greater leakage trouble in the boiler feed pump joints, castings and clearances. These difficulties become more pronounced as the pressure is raised and the mass of the pump parts becomes greater. As a result of this, practice seems to be tending toward supplying water to the boiler feed pump suction from the deaerator or bleeder heater operating at outlet water temperature of from 225 to 275 F and pumping water at boiler feed pump discharge pressure through the bleeder heaters operating at higher temperatures.

Drain Pumps for High Pressure Heaters and Steam Reheaters

Considerable trouble has been experienced with the drain pumps for high pressure bleeder heaters and steam reheaters. A number of such pumps are now in service, however, and are reported to be operating satisfactorily after some modification. Because of the high cost of these pumps and the troubles experienced with past designs, many stations are sacrificing the increased efficiency to be obtained by their use and are cooling the drips in some manner before returning the water to the boiler feed system.

Vacuum-Tube Type Bin Indicator

On bins of low height an elaborate type of bin indicator is not warranted. Also where head room is little or space is at a premium it might be impossible to use a mechanical type of indicator. For such locations the vacuum-tube type has possibilities. The characteristics of the radio type or three-element vacuum tube are used because this gives a means of varying a flow of current by a static potential condition; eliminating the necessity of making, breaking or changing current flow in the bin.



Sketches showing manner of operation

The sketch shows the general manner of operation. A battery, *A*, of suitable potential is used to light the filament thereby causing an electrostatic field to be set up within the tube because of the emission of negative electrons. The plus side of a *B* battery is connected to the tube plate through a relay, *R*, which takes the place of a telephone set, in the average radio connection. The negative electrons are thus caused to bombard the plate resulting in current flow, energizing relay *R* and opening the L_1-L_2 circuit. The negative side of a *C* battery is connected to a metal insert in an insulator such as at *X* and *Y* in the detail (upper right) which represents enlarged sections at points 1 and 2 the latter being any location desired in the bin, and the former any other point in the bin.

With pulverized coal in the bin in contact with points *X* and *Y*, the negative *C* battery potential is brought to the vacuum tube grid, producing a reduction of the plate current. By proper choice of grid potential for the tube and suitable plate potential the relay *R* will be dropped, energizing the alarm circuit L_1–L_2.

The features to be particularly noted are:

1. No current flows in the grid circuit; consequently there is no current in the bin.
2. There is no current broken at points such as 2; consequently there is no arcing in the bin.
3. The plate potential is determined by the tube used and would approach the recommended tube maximum.
4. The grid potential is determined by the tube used but would always be a low value as compared to the plate potential.

With a succession of vacuum tubes connected as shown for *A* battery and additional relays *R* connected in parallel between *B* battery and the plates of these tubes, a condition is established whereby negative *C* potential may be brought to the grids of these tubes when the coal reaches the elevation of the disk to which the grid wire is connected.

This device may be used not only for fuel bins but in all places where the level to be indicated is that of a material which will permit a negative bias to be given to the grid.

At the Century of Progress

Engineers interested in smoke abatement will find much to attract their attention in the "Smoke" exhibit at the Century of Progress. Devices for indicating and measuring smoke are shown as well as the three general principles of soot and dust recovery, namely, cyclone separation, wet washing and electrical precipitation. Improved methods of domestic firing to minimize smoke and cut coal bills are illustrated by illuminated motion diagrams and mechanical firing is explained. Numerous statistics are included to emphasize the beneficial effects of smoke regulation, particularly in Chicago where railroad smoke in the past twenty years has been reduced from 43 to 3 per cent although domestic smoke has increased.

The exhibit is solely educational in purpose and is sponsored by the railroads in the Chicago area, certain coal operators and the Chicago Smoke Regulation Department.

Determining the True pH Value

By D. S. CLARK
Purdue University

The author reviews the work of Evans and of Perley in determining true pH values of unbuffered waters and concludes that for routine power plant operation a standard of satisfactory performance could be determined without a knowledge of true pH values. He advocates employment of the electrical resistance method.

VARIOUS industrial processes, as well as power production, involve the control of alkalinity (or acidity) within certain limits, especially to prevent corrosion. Even in the human body, if certain conditions of alkalinity are maintained, the person precludes the distasteful payment for deferred maintenance and consequent ill health. The standard method of reporting the degree of alkalinity is expressed as the pH value.

The pH value indicates the degree of concentration of hydrogen ions, the term ion meaning an electrically charged infinitesimally small particle of matter. These pH values range from 1 to 14. The product of the concentration of hydrogen (H) ions and hydroxyl (OH) ions is 10^{-14} grams per liter of water; and from an electrolytic viewpoint, neutrality occurs with equal concentration of both the hydrogen and hydroxyl ions, 10^{-7} grams of each, or a pH value of 7. Thus the pH value is the logarithm of the denominator of the fraction indicating the concentration of hydrogen ions; values under 7 indicate a high concentration of hydrogen ions (acid condition) and values over 7 indicate a high concentration of hydroxyl ions (alkaline condition). These values obtain only under the temperature and pressure conditions at which they are determined.

The pH values are normally determined near atmospheric pressure and ordinary room temperature even if the water is to be used under an entirely different set of conditions. The higher the water pressure and temperature maintained, the greater will generally be the pH value to produce inactivity. While a pH of 7.5 appears to be satisfactory for a cold brine solution to produce chemical inactivity, a larger pH value must be maintained in a power plant. For comparatively low pressures and temperatures a pH value of 9.5 may suffice, but a more usual value is 10.5 to 11.5. Of course condensate will indicate a much lower value if some of the CO_2 has come over from decomposition of carbonates or if degasification is incomplete. Apparently, the pH value also changes when the water in the boiler is subjected to high temperatures and pressures. The circulation and rate of heat transfer may also affect the pH value.

Accurate determination of the pH value can be made electrically by determining the resistance to the flow of electric current. The antimony electrode is considered accurate within 0.2 pH from pH of 2 to 12, but the glass electrode is preferable. These determinations are normally under room conditions.

Generally, however, the colorimetric method is to be preferred. In this case a water sample of definite volume is mixed with a definite volume of indicator of known concentration producing a characteristic shade; then by comparison of this shade with a standard vial of the indicator, the pH value is obtained. A large number of indicators are available for certain pH values from 0.2 to 13.6, but the band covered by any one indicator is narrow. Indicators give accurate results for well buffered solutions, but introduce inaccuracies in unbuffered or only slightly buffered solutions. The term buffered means a solution capable of maintaining a nearly constant pH value when an acid or base is added. The presence of acetates, phosphates, citrates or borates insures a buffer action which also depends on the nature of concentration of these constituents, upon the type of acid or alkali added, and upon the pH region of measurement.

Indicators act either as weak acids or as bases, and have considerable effect upon the measurement of pH values, especially upon slightly buffered solutions if there is absorbed CO_2 or other oxides or gases.

J. N. Evans, in COMBUSTION, October 1933, outlined a method for determining true pH values of unbuffered waters found in power plants by taking certain precautions to avoid contamination and by making proper analysis. The indicators are buffered to some extent so that when they are mixed with the unbuffered water sample, the resulting mixture has a pH value which will not be the true pH value of the water, unless the pH of the indicator is the same as that of the sample of water. If two indicators are used on samples of the same water, the indicator with the pH above the true pH value of the water would show too great a pH content; whereas the indicator with a pH below that of the water would indicate too small a pH value. True values could be accurately obtained if the pH value of the water were at the midpoint of the indicator, or had the same pH value as the indicator. If two consecutive indicators were used and the results were obtained as above, the true pH value could be assumed to be between the two values obtained by indicators, whose midpoints have pH values above and below the true pH value of the water.

Another method (the Kolphoff method) consists of varying the pH value of the indicator until no change in pH value occurs when it is mixed with the water. In any event indicator solutions must be checked constantly by comparing the color with that of a sealed vial obtained from the indicator manufacturer and should be corrected by the addition of dilute HCl or NaOH.

Mr. Evans suggests the following precautions: All equipment should be chemically clean; hard glass should

be used in preference to soft glass; rubber or paraffine-coated cork stoppers should be employed; stoppers should not be laid on their side nor wetted portion touched by the fingers; sampling lines should be flushed out several hours to make sure of chemical cleanliness; the sampling line should be carried to the bottom of the flask or sampling bottle and the sample allowed to overflow for several minutes to prevent air contamination; samples should be cooled to room temperature before they are allowed to come in contact with air; use of a pipette from below the water surface in the container to below the surface in the test tube (formerly charged with the indicator) precludes pouring and shaking, but insures proper mixture. The color of the mixture is then matched with the standard.

Certain curves were drawn by him for the particular water tested and the explanation reflected accurate work. These curves showed a calculated true curve of pH values drawn against actual measurements of milligram equivalents of acids; and bases added, and another curve supplied this information with the range of values of thymol blue, cresol red, phenol red, bromthymol blue and chlorphenol red. These curves apparently verified his method for determining true pH values.

This method seems to give a close approximation of the true pH value and should approach in accuracy those obtained from well buffered waters which George A. Perley[1] says are within 0.2 pH units.

However, is the determination of the true pH value as a routine matter of appreciable assistance in plant operation? With given and comparatively uniform conditions, a standard of satisfactory performance could be determined without a knowledge of true pH values. This condition should be maintained by the use of any indicator within whose range the pH should fall. As long as satisfactory pH values were maintained by this method, the true pH under the room conditions furnishes little additional information.

It appears that a more accurate analysis could be made by measuring the resistance to flow of electric current. This could be delicately performed at the temperature and pressure maintained in the boiler. Proposed conditions could also be set up so that, with any sample of water, the performance under any proposed temperature or pressure could be predicted and the proper water treatment determined. The sample could be allowed to cool and a corresponding pH value determined at the lower pressure and temperature. This latter determination could be used for routine control either by the use of the electric method or by the colorimetric method for determining pH values.

The trends in steam power plant operation during recent years have been toward greater pressures and temperatures. While the condition of feedwater with reference to alkalinity and purity was of little consequence when plants were operated at pressures below 200 lb per sq in. and saturated steam, the feedwater problems become more complicated at 1200 lb per sq in. and 750 F. It should also be noted that there is considerable interest in steam generation at pressures near the critical at which point the alkalinity must have considerable significance. The maintenance of the pH value within accurate limits therefore becomes of major importance.

[1] Perley, George A.—Measurement and Control of Hydrogen Ion Concentration: Chemical and Metallurgical Engineering, August 1933.

Effect of Temperature on the Properties of Metals

The A.S.M.E.–A.S.T.M. Joint Research Committee on Effect of Temperature on the Properties of Metals, at its June meeting, voted to draw up a definite plan, for submission to letter ballot, for experimental study of methods of evaluating the load-carrying ability of metals under prolonged stress at high temperatures. The "creep" of selected materials will be studied by test runs to be carried out, not merely for 1000 or 2000 hr, but for three years, or say 25,000 hr, in order that the validity of various methods of approximation and extrapolation and the relation of various "short-cut" methods to actual long-time performance may be evaluated.

It also voted to study experimentally the progressive changes in toughness, during long exposure to high temperatures, of the 18-8 stainless steel whose creep properties have already been studied in detail.[1] This continuation of the prior work on this steel is aimed to throw light upon the fact that this lot of material, though free from added "stabilizing" elements, was not embrittled by long sojourn under load at high temperatures in the creep tests. The question whether this austenitic steel passed through a brittle stage, without evidence in the creep curves of any change in load-carrying ability, and then recovered from its brittle state, or whether it never did become embrittled, is of both theoretical and industrial importance. A material whose other properties have been so thoroughly studied as is the case with this steel, is especially suited for such a study.

Another new activity is a correlation of data on the effect of temperature on metal-to-metal wear, galling and sticking. Users and makers of valves that operate at elevated temperatures find this an important problem in which available information is chiefly of an empirical nature. It is hoped to aid in the transition from empiricism toward a more sound basis for engineering design and selection of materials.

[1] Reported in the July Transactions of the A.S.M.E.

Performance of British Power Stations

That the performance of British central power stations is steadily improving is shown by a report just issued by the *Electricity* Commission. With 489 stations reporting the average coal consumption for 1933 was 1.65 lb per kwhr generated. In 1932 it was 1.74 lb, the improvement having been due largely to the inclusion of several new and remodelled stations during the past year and the closing down of some obsolete stations. This figure of 1.65 is still appreciably higher than the average of 1.45 lb per kwhr in the United States, but conditions are not strictly comparable. The total amount of electricity generated by these stations in Great Britain was slightly over 14,390,000,000 kwhr.

The most economical performance for the whole year was that of the Clarence Dock Station at Liverpool which showed an average of 1.12 lb per kwhr and a corresponding thermal efficiency of 26.00 per cent. This was slightly exceeded by both the Ironbridge and the Battersea Stations with thermal efficiencies of 26.84 and 26.15, respectively. However, neither of these stations had been in service for the entire year.

REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

The Design and Use of Instruments and Accurate Mechanism

By T. N. Whitehead

In the preface to this book, Professor Whitehead says, "It must have occurred to every one conversant with the literature of engineering, and of instrument design in particular, that, in spite of tremendous expansion, the basic principles have been singularly stable for a very considerable time; this is a tribute to the ability of those engineers in the past who laid these foundations, but it is also a warning that the time has come to take stock of the position."

He then proceeds to do this stock-taking, to examine the validity of assumptions and principles on which instrument design is based and to analyze the actual physical causes of inaccuracy.

Professor Whitehead divides into three groups the various errors to which instruments and other precise mechanisms may be liable, each group resulting from a characteristic type of fault in one or more elements. In Part I he discusses these faulty elements and their resulting errors; in Part II he considers these defects in relation to practical problems of design and use.

This book contains 283 pages, size 6 × $8^3/_4$ overall. Price $3.50.

America's Capacity to Produce

By Edwin G. Nourse and Associates

This is the first volume in a series of four studies, undertaken by The Brookings Institution, dealing with the distribution of wealth and income in relation to economic progress. The present volume deals with America's capacity to produce during the period from 1900 to 1930 with the capital goods and labor she then possessed. Subsequent volumes will deal with "America's Capacity to Consume," "The Formation of Capital" and "Income and Economic Progress."

The purpose of the study is to determine whether defective distribution of the national income, and consequent inadequate purchasing power among the masses, is a primary cause of our economic difficulties, and whether our activities might be organized on a sustained level which would provide ample food, clothing, shelter and reasonable education and recreation for all.

In the present volume chapters are devoted to agriculture, coal and coke, petroleum, copper, cement, food products, textiles and clothing, automobiles, paper and printing, iron and steel, electric power, miscellaneous manufacture and transportation. Numerous charts and statistics amplify the analysis. The conclusions arrived at are that our productive system as a whole was operating at about 80 per cent of capacity in 1929, but due to certain limiting factors it would have been impossible to take up this slack completely, although greater coordination would have permitted taking up a part of it.

The book contains over 600 pages, $5^1/_2$ × 8 in., and is bound in cloth. Price $3.50.

A Manual for the Design of Piping for Flexibility by the Use of Graphs

By E. A. Wert, S. Smith and E. T. Cope

A collection of relatively simple charts and tables which enable the designer to avoid the laborious computations ordinarily involved in piping problems. Examples are included to show the use of the curves and equations. The work is based on investigations and practice of The Detroit Edison Company over a period of more than ten years which have resulted in the evolution of exact methods of design. Much of the work was reported from time to time in A.S.M.E. papers by the authors, and the present book is an amplification and rearrangement of the material in these papers. Only a very limited edition of the book has been printed to assist engineers who are engaged in piping layouts.

The book contains 130 pages, $8^1/_2$ × 11 in., 36 figures and 49 plates and is cloth bound. Price $2.50.

Great Men of Science

By Philipp Lenard
Translated from the German by H. Stafford Hatfield

Great Men of Science vividly portrays the lives and works of more than sixty outstanding scientists of all nationalities, each of whom has contributed some new idea of major scientific importance. The period covered stretches over some two thousand five hundred years, from Pythagoras of Samos to Friedrich Hasenöhrl. Among the men discussed are Euclid, Archimedes, Copernicus, Kepler, Pascal, Descartes, Newton, Papin, Watt, Cavendish, Oersted, Ampère, Ohm, Weber, Faraday, Helmholtz, Darwin, Maxwell and Hertz.

Professor Lenard, author of this book, is a well-known German physicist. Long and thorough research preceded his writing of this book. Not only were the historical works of science covered, but the writings of scientists themselves were studied to ascertain just which men had made original contributions.

The sketches are of varying length, some quite brief, particularly those of the earliest investigators, and others covering a number of pages. But in each the nature of the advance in knowledge is brought out and, in as far as possible, salient biographical facts of the subject's life are given.

The book contains 382 pages, size 6 × 9, name and subject indexes and is illustrated with sixty-two reproductions of unusual portraits. Price $3.00.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Belt Conveyor Idlers

Bulletin No. 72 issued by the C. O. Bartlett & Snow Company, Cleveland, contains a description of belt conveyor idlers made by that company, together with dimensions, engineering data relative to spacing and capacities, and prices.

Centrifugal Pumps

Information and data concerning Types C, CA and CB Worthington centrifugal pumps are contained in a bulletin just released by the Worthington Pump and Machinery Corporation, Harrison, N. J. These pumps are designed for either belt or motor drive and are built in capacities ranging from 10 to 3400 gpm and for heads from 10 to 80 ft.

Dust Collectors

A discussion of flue dust collection by the cyclone method, based on researches carried on at the Brooklyn Polytechnic Institute, with particular reference to multiple small diameter cyclones is contained in a bulletin just issued by the Prat-Daniel Corporation, New York. A description of the Thermix Multi-cyclone is given together with operating data from a number of installations in both industrial and power plant work.

Electro Pneumatic Valve

Information concerning a new line of electro-pneumatic valves is contained in a leaflet recently issued by Westinghouse Electric and Manufacturing Company. These valves are used to control the supply of compressed air to pneumatically operated apparatus such as electro-pneumatic switches, reversers, door engines, whistles, etc. Two general types are discussed; namely, standard and inverted types. They are available in several sizes and are supplied for both a-c and d-c service. Specification and dimensions for each valve are included.

Flexible Couplings

A new general purpose coupling is the subject of a publication, entitled Type WH Flexible couplings, recently issued by the Westinghouse Electric & Mfg. Co. Designed for use in connection with gearmotors, speed reducers and other industrial drives, this coupling requires no lubrication, is easily inspected and is safe in operation. In this illustrated leaflet are described the distinctive features, construction, ratings and dimensions of the coupling.

Impact Pulverizers

Bulletin No. 13 just issued by the Whiting Corporation, Harvey, Ill., describes and illustrates the line of impact pulverizers developed by that company. These range in capacity from 350 to 3000 lb of coal per hour and are also suitable for pulverizing a variety of substances such as talc, lime, shales, chemicals and colors.

Insulating Blocks

Folder "IN-28-A" issued by the Johns-Manville Company, New York, describes the "Superex" insulating blocks developed by that company. These blocks are applicable to furnaces and boiler walls and the folder contains a table of recommended thicknesses of Superex both when used alone and in combination with other insulating materials.

Locomotive Cranes

A new 16-page illustrated catalog on locomotive cranes has recently been completed by Link-Belt Company, Chicago. Tables of clearance dimensions and rated lifting capacities are given for machines for operation by either a gasoline, Diesel, electric or steam-driven power unit. The book includes not only standard gage machines but also cranes for operation on wide gage tracks and for use at radii as large as 110 ft.

Maintenance of Reciprocating Parts

The Linde Air Products Company, New York, has just issued a new publication on oxy-acetylene welding. This deals with the application by the oxy-acetylene process of wear-resisting bronze to the wearing surfaces of sliding parts. It makes a valuable addition to the existing literature on the subject of bronze-welding by reason of the comprehensive manner in which it treats one of the most important applications of the oxy-acetylene process. After a brief general discussion, the advantages of bronze-surfacing as an economical and efficient means of reclaiming pistons and similar wearing parts are set forth. The wide scope of the application is detailed at some length by mentioning examples of successful use of the process in a number of different fields. Other sections of the booklet discuss frequency of application, characteristics of certain applications, and the importance of wear-resisting bronze welding rod, while the final section is devoted to a complete description of the correct procedure to be followed in the resurfacing operation.

Portable Compressed Air Cleaner

Compressed air for blowing dust and dirt accumulations from motors, generators, switchboards, engines and other power plant equipment, when taken from the ordinary air lines, often contains moisture and oil. To obviate this the Hagan Corporation, Pittsburgh, has brought out a portable compressed air cleaner which consists of an 8 in. tank on wheels to which is attached a centrifugal separator. This is described in a bulletin just issued by that company.

Pumps

Catalog No. 3 recently issued by The Deming Company, Salem, O., describes and gives engineering data, tables and general information concerning its line of pumps.

Resistance Thermometers

For measuring temperatures from −300 to +1000 F the Brown Instrument Company, Philadelphia, has developed a line of resistance thermometers which are described and illustrated in its catalog No. 9001. These thermometers are applicable to various industrial processes, oil refineries, hospitals, hotels and power plants. They operate on the basic principle of the Wheatstone Bridge circuit.

Speed Reducers

A new 32-page illustrated catalog No. 1415, with horsepower and other engineering data, dimension diagrams, etc., has recently been issued by Link-Belt Company, Chicago. The book covers single, double- and triple-reduction units of herringbone gear type; also a full line of flexible couplings.

Steam Booster Compressors

Worthington Pump and Machinery Corporation, Harrison, N. J., has just issued a bulletin dealing with the design of its line of steam booster compressors for use where higher pressure and temperature steam is required than that afforded by the existing boiler installation.

Surface Condensers

Bulletin W-200-B2 issued by Worthington Pump and Machinery Corporation, Harrison, N. J., describes its folded-tube layer type condenser with welded steel shell construction. In this design the tubes are grouped into one or two layers, depending on the size of the condenser, and each layer is folded upon itself to form a tube bank presenting a maximum number of front line tubes to the incoming steam, and providing an exit lane from the interior of the tube bank to the air-cooler section.

Water Level Detector and Water Gage

Diamond Power Specialty Corporation, Detroit, has recently issued two attractive folders describing its new water level detector and its bi-color water gage. The former is operated by pressure differential instead of weights, floats or buckets.

NOTICE

Manufacturers are requested to send copies of their new catalog and bulletins for reviews on this page. Address copies of your new literature

to

COMBUSTION

200 Madison Ave., New York

ENGINEERING

1—Procedure Handbook of Arc Welding Design and Practice

(Enlarged Edition)

454 pages Price $1.50

This handbook is a compendium of pertinent information and accurate data on the subject of the art of arc welding, its applications, and design procedure for the most efficient use of the process. It was prepared not only for all welders and users or prospective users of the electric arc process of welding but also for those responsible for the design of products which may be built by welding.

The book is divided into eight principal sections or parts, each of which deals with an important phase of arc welding and its application in a clear, concise manner, amply illustrated with detailed drawings and photographs. The main headings are as follows: Welding Methods and Equipment; Technique of Welding; Procedures, Speeds and Costs for Welding Mild Steel; Structure and Properties of Weld Metal; Weldability of Metals; Designing for Arc-Welded Steel Construction of Machinery; Designing for Arc-Welded Structures; Typical Applications of Arc Welding in Manufacturing, Construction and Maintenance.

2—Vocational Guidance in Engineering Lines

521 pages 6 x 9 $2.50

A compilation of chapters written by engineering experts has just been published by a special committee of the American Association of Engineers under the chairmanship of Dr. J. A. L. Waddell. Each chapter is the work of a man who is outstanding in his particular branch of engineering, and each tells in a non-technical way of the nature of that kind of engineering, of the qualifications necessary for success in that particular line of work, and of the probable or average compensation to be expected.

While engineering accomplishment is featured, it is frankly pointed out that "of the hundreds who faithfully devote themselves to the task, only a few are destined to receive any significant reward—in either money or fame." Because of this, it requires the maximum of natural aptitude and of liking for the work, and those who do not possess a thorough ground in mathematics and physics are advised against taking up an engineering course.

The book is unique. It is authoritative and should be carefully read by all high-school students who contemplate engineering as a career. Parents and teachers will find it not only informative but of invaluable assistance in guiding the student and judging his fitness.

3—The Chemical Formulary First Edition—1933

550 pages $5^1/_2$ x $8^1/_2$ Price $6.00

Chemists, engineers, technical workers, purchasing agents, executives, instructors, etc., will find this condensed collection of valuable, timely and practical formulas for making thousands of products in all fields of industry of great assistance. It bridges the gap between theory and practice. More than sixty industrial chemists, professors and technicians in many branches of industry have cooperated to make this the most modern work of its kind available.

The Chemical Formulary contains methods for making:

Abrasives, Adhesives, Alloys, Anti-freezes, Anti-corrosives, Artificial Rubber, Artificial Stone, Artificial Leather, Automobile Specialties, Boiler Compounds, Candles, Carbon Paper, Celluloid, Cement, Cement Waterproofing, Chromium Plating, Cleaning Compounds, Concrete Specialties, Cork Compositions, Cutting Oils, Disinfectants, Driers (Paint), Dyeing, Explosives, Extracts, Fertilizers, Fire Extinguishers, Fireproof Paints, Flotation Agents, Fuels, Gems, Grease, Lubricating, Ink, Printing, Ink, Specialties, Insulation, Electrical, Japans, Lacquer, Leather Finishes, Lubricants, Metal Plating, Metal Polish, Molding Compounds, Oilskin, Paint, Acid Proof, Paint, Cold Water, Paint Remover, Paper & Pulp Specialties, Paper Coating Petroleum Specialties, Pigments, Plastics, Plasticizers, Refractories, Rubber Compounding, Rustproofing, Safety Glass, Shoe Dressings, Solidified Oils, Soluble Oils, Solvents, Stains, Wood, Stripping Solutions, Tanning, Varnish, Bakelite, Varnish Removers, Viscose Specialties, Vulcanization, Waterproofing, Wax Emulsions, Wood Filler, etc., etc.

4—Power Supply Economics

By Joel D. Justin and William G. Mervine

276 pages 6 x 9 $3.50

This book was written primarily for the executives and engineers of power companies and industrial concerns who may, in greater or lesser degree, be charged with the responsibility of maintaining or providing a dependable power supply.

Although the book treats of the broad general principles of the economics of power supply and does not go into technical details, the authors believe that engineers charged with the investigation, design and construction of power plants and the utilization of such plants to obtain the minimum system production cost will find in it much which is of interest.

Power Supply Economics indicates and describes principles and methods of analysis which will prove helpful in finding the most economical answer to problems which are constantly arising.

5—Steam Power Plant Engineering

By G. F. Gebhardt

1036 pages Price $6.00

One of the truly standard reference books on mechanical engineering. It is a necessary part of the equipment of everyone who has to do with steam power plant engineering.

6—World Economic Survey (1932–33)

345 pages $6^1/_4$ x $9^1/_2$ Price: cloth bound $2.00, paper bound $1.50

The *World Economic Survey 1932–33* is the second volume of an annual series issued by the League of Nations. The information it contains was collected from all over the world by the Economic Intelligence Service of the League, and it therefore provides an authoritative survey of what perhaps was the most critical year in the world economic history.

7—Chemical Engineers' Handbook

By Dr. John H. Perry and W. S. Calcott
Assisted by a staff of specialists

2609 pages 5 x 7 Price $9.00

A handbook for the practicing engineer in the field of chemical and process industries. In this field it forms a companion treatise to Marks in the mechanical engineering field. Sixty-three specialists in various branches have contributed to the thirty sections of the book. Mechanical and electrical engineering, such as power generation and application, transmission, fuels, refrigeration, materials of construction, etc., are dealt with to the extent of acquainting the chemical engineer with fundamentals, types and performance to be expected. Conversely, the mechanical engineer will find the book of great assistance in affording a knowledge of processes that utilize the services for which he is responsible.

8—Elements of Heat-Power Engineering—Parts II and III (Third Edition)

By W. N. Barnard, F. O. Ellenwood and C. F. Hirshfeld

Part II: 871 pages 6 x 9 Price $5.50
Part III: 415 pages 6 x 9 Price $4.50

This work is in three volumes. Part I covering "Thermodynamics" was completely rewritten in 1926. Parts II and III, covering, respectively, "Steam Generating Apparatus and Prime Movers, Fuels, Combustion and Heat Transmission" and "Auxiliary Equipment, Plant Ensemble, Air Conditioning and Refrigeration," were completely rewritten in 1933 to form the third edition. In doing this the books have been brought in line with current practice and offer an excellent combination of underlying theory and its reduction to practice. The descriptive range and performance of equipment of different types and makes are unusually complete, typical installations involving a variety of arrangements are included, and the economics of power plant design are discussed.

9—Draft and Capacity of Chimneys

By J. G. Mingle

339 pages Illustrated Price $3.50

The subject matter of this book has been developed primarily from a theoretical standpoint and then amplified by experimental data gleaned from actual practice.

The author observes that draft, even to the expert, frequently contains an element of mystery, and that there is often a great deal of confusion and misconception on the subject. A careful study of this book will give a thorough and practical knowledge of this important subject. The book is profusely illustrated with graphs and charts. Many valuable tables are included and the index has been prepared for ready reference.

BOOKS

10—A.S.M.E. Power Boiler Code (1933 Edition)

314 pages 5½ x 8 Price $2.50

The new edition of the *A.S.M.E. Power Boiler Code* incorporates the revisions, extensions and additions to rules and specifications that have been made during the past three years. It contains Sections I, II and VI of the *A.S.M.E. Boiler Construction Code*, covering, respectively, Power Boilers, Material Specifications, and Rules for Inspection.

11—Bailey's Handbook of Universal Question and Answers (Sixth Edition)

264 pages 4¾ x 6½ Price $2.00

The questions and answers contained in this Handbook are those that have been universally asked by examining boards and were compiled from over four hundred examination papers, including tests for firemen, engineers and boiler inspectors. It gives information on the subjects of boilers, pumps, fuel consumption, valves, heating systems, engines, etc., and will be of assistance not only to those studying for any grade of license in this country or in Canada but also to the practical engineer and fireman.

The author, A. R. Bailey, is intimately acquainted with the needs of practical engineers and firemen and of candidates for licenses, having served as engineer and boiler inspector in the states of Massachusetts, Ohio, Pennsylvania and Michigan, and as safety engineer for the Lincoln Motor Company, Detroit. The sixth edition of this book, recently published, has been brought thoroughly up-to-date.

12—The Calculation of Heat Transmission

By Margaret Fishenden and Owen A. Saunders

280 pages 5¾ x 9¾ Price $3.00

The Calculation of Heat Transmission by Dr. Margaret Fishenden and Owen A. Saunders of England was prepared under the auspices of the Fuel Research Board of the Department of Scientific and Industrial Research. In it an attempt is made to bring together in accessible form the various experimental results described in the mass of scattered literature now available on the subject. Complicated theory and specialized technical applications have been avoided, but, wherever feasible, results have been interpreted and compared in the light of fundamental principles of conduction, convection and radiation.

The main chapter headings are as follows: Radiation; Calculation of Radiation Heat Transfer; Emission and Absorption of Radiation by Gases and Flames; Conduction; Calculation of Conduction Heat Transfer; Convection; Natural Convection in Gases; Forced Convection in Gases; Convection in Liquids; Heat Transfer Calculations.

13—Combustion in the Power Plant (A Coal Burner's Manual)

By T. A. Marsh

255 pages Price $2.00

The author's discussion of coals and combustion is simple and understandable. His consideration of equipment—stokers, boilers, furnaces, fans and auxiliaries—is thoroughly practical. He tells how to select a stoker for the best available coal; how to design furnaces and arches; how to analyze draft problems and design chimneys, gas flues and boiler passes; how to purchase coal and calculate steam costs. He gives to every phase of his subject a practical interpretation that makes this book of exceptional value to men actually identified with steam plant design and operation.

14—A Handbook of English in Engineering Use

By A. C. Howell

308 pages Price $2.50

Here is a real up-to-the-minute handbook, that should be on the desk of every technical writer. Most engineers today have occasion to do considerable writing and for those who have some doubt as to their ability to express themselves clearly, accurately and in acceptable form, Professor Howell's book will be of very definite value. The author takes a very practical point with regard to the engineer's professional use of language. Chapters are devoted to word usage and idioms, sentence and paragraph structure, composition, punctuation and the mechanics of writing and grammar. Examples cover letters, reports and technical articles.

15—Steam Tables and Mollier Diagram

By Joseph H. Keenan

Price $2.00

These new Steam Tables, extending to a pressure of 3500 lb. per sq in. and a temperature of 1000 F, were developed from the latest experimental data secured by investigators in laboratories of Europe and those of the United States. The Symbols used in this work are taken from the latest test prepared by the A. S. A. Sub-Committee for Heat and Thermodynamics. A large copy of the new Mollier Diagram (23″ x 34″) is also included.

Any Book in Print May be Ordered Through Our Book Dept.—Use Order Form below

16—Thermostats and Temperature Regulating Instruments

By Roosevelt Griffiths

157 pages $5.00

This book will prove particularly helpful to the testing engineer who must have the latest data on the automatic control of the temperature of an enclosure or bath. To him, the right selection of a thermostat to suit his particular requirements is obviously of great importance.

In addition to the laboratory types of thermostats described, an account is given of coarser forms which find application in certain industrial operations.

The following chapter headings indicate the scope of the subject matter of this volume: Thermostats Based on the Expansion with Temperature of Gases; Thermostats Based on Expansion of Liquids (Laboratory Types); Industrial Types of Thermostats Based on the Expansion of a Liquid; Mercury Expansion Thermostats; Thermostats Based on the Boiling Points of Liquids; Thermostats Based on Expansion of Solids; Bimetallic Type of Regulator; Resistance Thermostats; Temperature Control Using Radiant Energy; Contact Type of Regulator; Potentiometric Regulators; Induction Regulators; Low-Temperature Control.

17—Problems in Human Engineering

By F. Alexander Magoun

585 pages Price $2.60

Here is a real case book in Human Engineering, built around fifty typical difficulties and emergencies that business men have actually had to face. The questions are those that confront men in all ranges of business success, involving relations with superiors, equals, competitors, inferiors, customers, labor and the opposite sex. Almost every personality trait that can help or hinder a man at work is brought into the limelight of discussion.

Following the brief statement of the problem the reader finds a group of the actual answers that students in the Humanics class at the Massachusetts Institute of Technology, which is being conducted by Professor Magoun, worked out and handed in. Good and bad, pro and con, they have been selected to preserve the controversial nature which makes this problem book so stimulating.

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Book Nos......

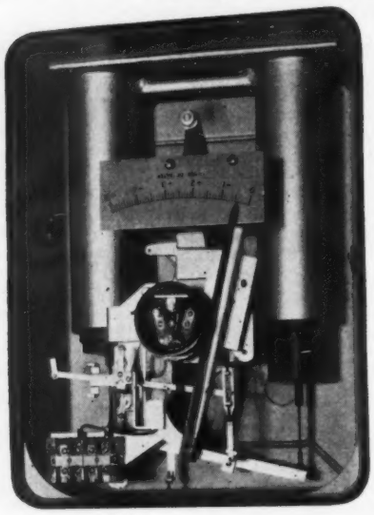
NEW EQUIPMENT

of interest to steam plant engineers

Control Trip to Prevent Explosions

To guard against explosive mixtures of fuel and air when lighting off pulverized-coal, gas or oil-fired boilers, Bailey Meter Company, Cleveland, Ohio, has developed a control trip which withholds fuel feed until the boiler is thoroughly purged.

The mechanism, as will be noted, consists essentially of two oil-sealed bells suspended from a beam to measure air flow through the boiler. A draft connection from the right-hand bell to the boiler furnace, and a similar connection from the



left-hand bell to the last pass provides for the use of draft loss through the boiler as a measurement of air flow. The entire mechanism, including oil-sealed bells, snap-acting contactor and indicating pointer, is enclosed in a dust and moisture-proof pressed steel casing of attractive design.

Although this control device is provided with an indicating pointer for calibration and checking, its primary function is to operate the snap-acting contactor shown in the circular casing between the two oil-sealed bells. This contactor is connected to the air flow mechanism by linkage in such a manner that it is necessary to run the rate of air flow through the boiler up to approximately 60 per cent of capacity before the contactor snaps closed and permits operation of the fuel feeder motor relay or control valve. Once this contactor goes to the closed position it remains there until the air flow value approaches zero, thereby permitting operation of the unit throughout its entire control range without tripping out the fuel feed.

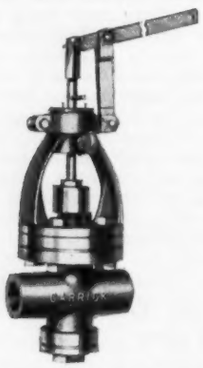
This simple control trip eliminates one of the most serious hazards encountered in the operation of units fired with fuels in suspension.

Blowers

A recent addition to the line of centrifugal compressors and exhausters built by the Roots-Connersville Blower Corporation of Connersville, Ind., is the single-stage Type "OIB" unit. In this design, the machines have their own shafts and bearings and are suitable for direct connection to standard electric motors or steam turbines, without special shaft extensions. They are also adaptable to V-belt or flat-belt drive. Impellers are furnished in aluminum or carbon steel in the standard construction, but special alloys can be supplied where conditions require. Open-type impellers are used in the smaller sizes, with closed type for larger machines. Each impeller is designed to meet specified requirements. The casings are ordinarily made of cast iron, but special alloys, to resist corrosive or abrasive action, can be supplied. Anti-friction bearings are used in smaller sizes, and sleeve bearings in the larger.

Adjustable Control Valve

The Carrick Type FT adjustable FLO-TROL valve shown in the illustration is of the moving plug type. The valve body and all external parts, except the lever, are of cast hard bronze for ordinary steam pressures and temperatures. For high steam pressures and temperatures the



body and head flange coming in contact with the steam are of cast steel. Other external parts are of gray cast iron. The operating lever is of monel and the stem of stainless steel. Although screwed connections are standard flange connections can be furnished. Although the valve is designed primarily for the control of steam it is entirely suitable for the control of other fluids, such as oil, gas or air.

The valve is generally controlled by some automatic device, such as a master control. In such a case the valve is part of a combustion control system. The lever of the valve is moved automatically to secure a variation of steam flow for speed control of the engine or turbine driving the stoker or fan. The manually adjustable feature of the valve makes it possible to secure the required range of speed to be effected by the movement of the valve lever. All adjustments can be made easily, while the valve is in service.

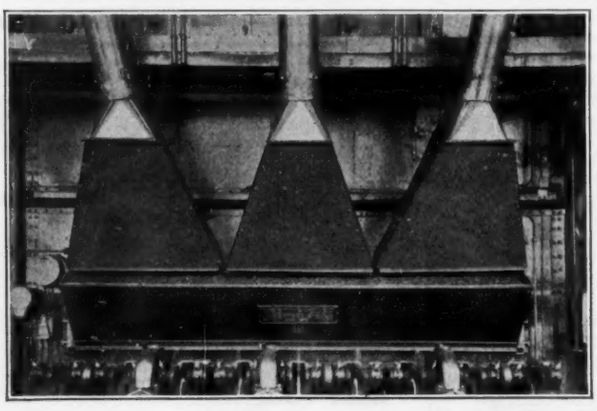
Bronze Gate Valve

The Kennedy Valve Manufacturing Company, Elmira, N. Y., has placed on the market a new heavy standard bronze gate valve designed for 150 lb working steam pressure and 250 lb working water, oil or gas pressure.

One of the features of these new valves is the large bonnet hex which is placed close to the body to make the entire valve more rigid and also to assist easier removal of the bonnet and stem assembly when the valve is installed with close clearances. Another feature is the design of the stem which is made of specially tough bronze, has an unusually large number of heavy contact threads, and has a flexible connection between the stem head and the disk, making stripping of threads almost impossible and prolonging the life of the valve. These valves are built in sizes up to 3 in.

Coal Distributor

In the operation of modern boilers with high ratings, it is essential that the coarse and fine coal be evenly distributed. If the fuel bed consists of coarse coal at some points and fine coal elsewhere, there will be an excess of air through the coarse coal and a deficiency of air through the fine coal, resulting in an uneven fuel bed and poor combustion. The Fairfield Engineering Company, Marion, Ohio, has lately been granted patents in connection with the design of its coal distributor. This employs an arrangement of fixed internal deflecting vanes. Two series of these vanes are used, diverging and running substantially parallel to the spreading sides of the chute. These, as soon as the chute is filled, form supply channels for multiple small feed streams covering the entire inner part of the chute, which flow under confinement in straight lines to the stoker hopper, without opportunity for spreading.



NEW EQUIPMENT—Continued

C-E Steam Washer

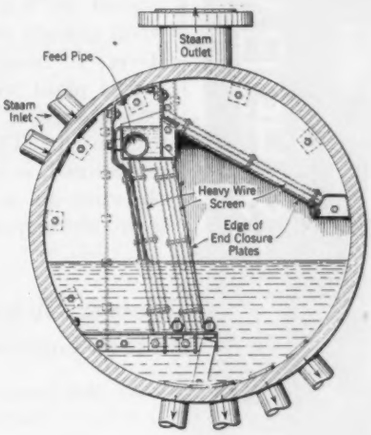
With the object of reducing the solid contents in the steam leaving the boiler and the consequent protection of the superheater and turbine blading, Combustion Engineering Company, Inc., has developed a steam washer for placing within the steam drum.

As shown in the illustration water from the feed box spreads over the initial screen and forms a curtain through which the steam must pass on its way to the outlet at the top of the drum. This washes the steam with the clean feedwater and removes much of the solid content. The subsequent screens through which the steam must pass are for the purpose of removing entrained water. The moisture content of the steam leaving the boiler drum is not increased as a result of the washing under these conditions and it is probable that the reduction in film tension actually decreases the tendency to carry over suspended particles of water.

The heavy wire screen sections are made up in panels of such size that they can be passed through the drum-head manholes. All except the overhead screens ahead of the steam outlet are assembled and secured in place without the use of bolts or the use of tools.

Where all steam from the boiler tubes and water walls enters on one side of the drum a single washer arrangement, as shown, is employed. If the steam enters on both sides of the drum a duplex arrangement of washers is necessary. This consists merely of a second set of screens on the opposite side of the drum.

While difficulties from the carry-over of solids in the steam have been more pronounced with high-pressure boilers, trouble from this source has also been experienced with boilers operating at around 400 lb pressure. By thus washing the steam with fresh feedwater it is possible to reduce the



solid carry-over to approximately one per cent of the solid content of the boiler water.

One of these steam washers has been in operation in a large central station for several months with very satisfactory results.

Thermo Master Regulator

To control the temperature of steam after it has passed through a reducing and desuperheating station, The Swartwout Company of Cleveland has developed a thermo master regulator consisting of a thermostat made up of two different pieces of metal having different coefficients of expansion. The operating element of the regulator is inserted in the steam line on the outlet side of the desuperheater. The power thus developed is transmitted through a lever to a three-way valve. This three-way valve admits pressure to or relieves pressure from the main diaphragm-operated valve controlling the water supply to the desuperheater. It is built for controlling temperatures as high as 1000 F and incorporates special safety features for protecting working parts in event of failure of water supply to the desuperheater. This regulator can also be used on any temperature control system where one large or a number of valves may be in operation and where it is essential that accurate temperatures be maintained.

Welding Electrodes

For general purpose welding the General Electric Company, Schenectady, N. Y. has brought out a heavily coated or shielded arc type electrode designated as Type W-22. This is suitable for the quality of work specified as Class I welding for pressure vessels by the A.S.M.E. Boiler Code. It may be used in any position and is said to have deep penetration properties.

More than 5,000 boiler plants of all types and sizes will testify to the outstanding performance of "Diamond" products:

DIAMOND "AUTOMATIC VALVED" SOOT BLOWERS

DIAMOND "LOOSE WINDOW" HIGH PRESSURE GAUGES

DIAMOND BI-COLOR WATER GAUGES

DIAMOND HIGH PRESSURE WATER COLUMNS

DIAMOND DESLAGGERS

DIAMOND AUTOMATIC AIR PUFF SOOT BLOWERS

Diamond Power Specialty Corporation
DETROIT, MICHIGAN
Diamond Specialty Limited
WINDSOR, ONTARIO

The SOCIETE
OUGREE-MARIHAYE
(Belgium)

Owners of Patent: No. 1,818,189

PROCESS
for the
PURIFICATION OF COAL

—permitting particularly the production from raw coal of coal and coke with less than one per cent ash for use especially for hydrogeneration, direct combustion without explosive motors, the manufacture of pure carbon electrodes for the electrometallurgy of light metals, etc.

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FOR THIS PATENT

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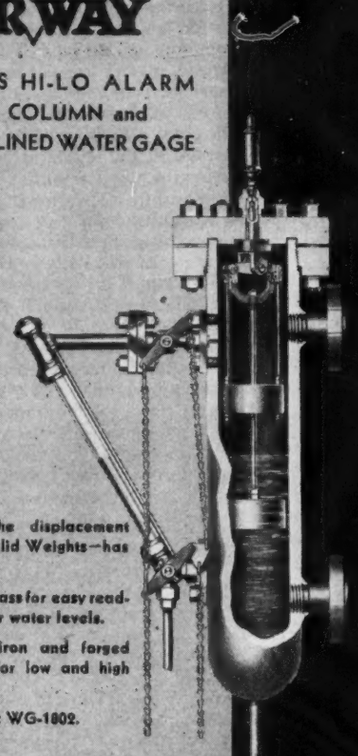
YARWAY

FLOATLESS HI-LO ALARM
WATER COLUMN and
SE-SURE INCLINED WATER GAGE

SOLID WEIGHTS—NO FLOATS



Operates on the displacement principle with Solid Weights—has no floats.

Inclined Gage Glass for easy reading of high boiler water levels.

Made of gray iron and forged steel in types for low and high pressures.

Send for Booklet WG-1802.

YARNALL-WARING COMPANY
Mermaid and Queen Sts. Philadelphia

ELECTRUNITE

STEEL & TUBES ELECTRIC WELD

BOILER TUBES

ELECTRUNITE Boiler Tubes last longer because they are more resistant to corrosion. And they resist corrosion for these reasons: the strip steel from which they are made is free from scabs, slivers and rolled-in scale. The surface of the tube is smooth inside and outside. Full-normalizing produces a uniform grain structure, even at the weld. The rolling of the strip gives the tube a dense surface inside and out.

These features mean a slower rate of corrosive attack, retarded pitting action and longer life. Yet these are only a few of the reasons why Electrunite Boiler Tubes have so quickly gained wide acceptance with boiler makers, contractors and users. Complete literature sent upon request.

STEEL AND TUBES, INC.
WORLD'S LARGEST PRODUCER OF ELECTRICALLY WELDED TUBING
CLEVELAND • • • OHIO
A UNIT OF REPUBLIC STEEL CORPORATION

Oppose Government Hydro Projects

As mentioned in the July issue of COMBUSTION the Alabama coal operators have applied to the federal court to enjoin the activities of the Tennessee Valley Authority from entering upon a large scale power business in that state. Since then Duke University at Durham, N.C., whose endowment is closely tied up with utility properties in the South, has filed a protest against a PWA grant of three million dollars to Greenwood County for a hydro-electric project on the Saluda River, it being claimed by the University that one textile plant will be the chief beneficiary and that the expenditure of federal funds for this purpose is not warranted. The National Coal Association, it is understood, is preparing to join forces with these other objectors in a vigorous campaign against widespread hydro development with federal funds.

Power Subjects at Iron and Steel Convention

At this year's convention of the Association of Iron and Steel Electrical Engineers to be held in Cleveland, September 18 to 20, there are scheduled several papers of interest to power engineers. Especially pertinent at this time is a paper on "Increasing the Output of Steam Power Plants by Superimposing High Pressure Turbines and Boilers." There will be a whole session devoted to lubrication. This will include papers on "Servicing of Steam Turbines, Diesel and Transformer Oils," "New Developments in Lubrication," and "Oiling System Installation—Piping and Arrangement." Another session will be devoted to welding. In connection with the meeting and technical sessions there will be held an Iron and Steel Exposition in the Cleveland Public Auditorium. Here, in addition to steel mill equipment, will be seen exhibits of combustion control equipment, anti-friction bearings, lubrication devices, motors and electrica control equipment.

Central Station Output

Following are statistics released by the Edison Electric Institute on the source and disposal of energy and sales to ultimate consumers for the first six months of 1934 compared with the corresponding period of last year.

	First 6 months 1934 Thousand kwhr	First 6 months 1933 Thousand kwhr	Per cent
Kilowatt-hours generated			
By fuel	25,492,912	20,855,064	+ 22.2
By water power	16,104,523	16,795,400	− 4.1
Total	41,597,435	37,650,464	+ 10.5
Additions to supply			
Energy purchased	1,226,169	985,307	+ 24.4
Imports	432,545	193,394	+123.7
Total	1,658,714	1,178,701	+ 40.7
Deductions from supply			
Used in elec. ry. depts.	348,670	356,829	− 2.3
Used in elec. depts.	685,466	606,914	+ 12.9
Total	1,034,136	963,743	+ 7.3
Total for distribution	42,222,013	37,865,422	+ 11.5
Lost in distribution, etc.	7,108,150	6,760,150	+ 5.1
Sales to consumers			
Domestic	6,387,262	6,059,240	+ 5.4
Commercial (small)	6,437,282	6,098,697	+ 5.6
Commercial (large)	18,236,187	15,165,851	+ 20.2
Municipal lighting	1,103,644	1,129,986	− 2.3
Street railways	2,239,975	2,007,042	+ 11.6
Railroads (electrified)	360,448	314,859	+ 14.5
Misc.	349,065	329,597	+ 5.9
Revenue from consumers	$911,786,700	$879,576,700	+ 3.7

EQUIPMENT SALES
Boiler, Stoker, Pulverized Fuel

As reported by equipment manufacturers of the Department of Commerce, Bureau of the Census

Boiler Sales

Orders for 96 water-tube and h.r.t. boilers were placed in June

	Number	Square Feet
June, 1934	96	209,251
June, 1933	121	361,034
January to June (inclusive, 1934)	436	1,245,056
Same period, 1933	383	1,146,250

NEW ORDERS, BY KIND, PLACED IN JUNE, 1933–1934

Kind	June, 1933 Number	June, 1933 Square Feet	June, 1934 Number	June, 1934 Square Feet
Stationary:				
Water tube	73	300,352	43	141,166
Horizontal return tubular	48	60,682	53	68,085
	121	361,034	96	209,251

Mechanical Stoker Sales

Orders for 169 stokers, Class 4,* totaling 34,294 hp were placed in June by 60 manufacturers

	Installed under: Fire-tube Boilers No.	Fire-tube Boilers Horsepower	Water-tube Boilers No.	Water-tube Boilers Horsepower
June, 1934	117	14,976	52	19,318
June, 1933	147	17,593	50	16,200
January to June (inclusive, 1934)	486	64,248	217	88,037
Same period, 1933	391	51,179	181	62,578

* Capacity over 300 lb of coal per hr.

Pulverized Fuel Equipment Sales

Orders for 4 pulverizers with a total capacity of 12,400 lb per hr were placed in June

STORAGE SYSTEM

	Pulverizers: Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Water-tube Boilers: Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
June, 1934	..	..	..	.....	..	....	....
June, 1933	..	..	..	.....	..	....	....
January to June (inclusive, 1934)	2	1	1	46,000	..	.....	.....
Same period, 1933	2	..	2	60,000	2	37,000	325,000

DIRECT FIRED OR UNIT SYSTEM

	Pulverizers				Water-tube Boilers		
June, 1934	4	4	..	12,400	4	16,000	138,000
June, 1933	11	7	4	52,090	11	63,415	501,420
January to June (inclusive, 1934)	31	22	9	252,610	23	208,475	2,144,700
Same period, 1933	34	23	11	160,240	27	174,673	1,483,360
					Fire-tube Boilers		
June, 1934	..	..	..	....	..	....	.....
June, 1933	4	..	4	3,000	5	7,500	30,800
January to June (inclusive, 1934)	4	..	4	4,800	5	7,500	41,000
Same period, 1933	9	2	7	7,700	10	14,150	64,900

For low-speed steam drives this COMPACT G-E GEAR-TURBINE

will.. CUT INSTALLATION COSTS
REDUCE MAINTENANCE
SAVE SPACE

Compactness of drive, a characteristic of the G-E gear-turbine, is provided by this 36-hp., 2000-rpm. unit, installed in one of the shops of a large Eastern railroad for driving a forced-draft fan.

INSTALLATION COST—Time and cost of installing a gear-turbine are minimized. Its close-coupled, compact construction permits ease of mounting and alignment.

MAINTENANCE — The gear-turbine, operating as a single, permanently aligned unit, naturally requires less attention than a turbine which delivers its output through a separate speed reducer.

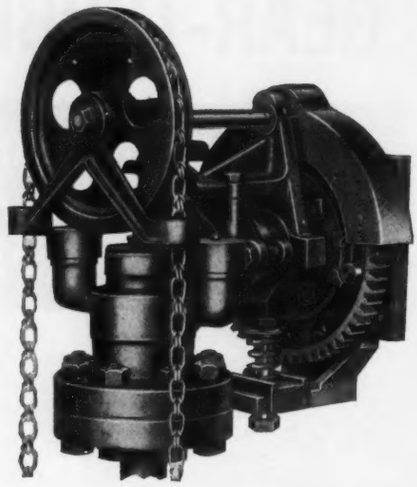
SPACE — The G-E gear-turbine requires but slightly more space than a straight turbine drive.

A G-E turbine specialist will gladly explain the advantages of the gear-turbine and assist you in selecting the proper unit for your requirements. Remember that G-E gear-turbines are available in capacities from 5 to 150 hp. and in speed ratios as high as 12 to 1. For particulars, call the nearest G-E sales office, or write to General Electric Company, Schenectady, New York.

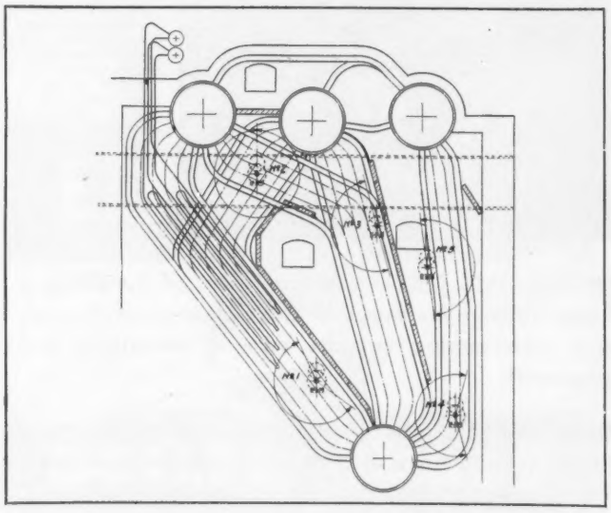
GENERAL ELECTRIC

720-225

PROVING ITS WORTH!



This is the new Balanced Valve-in-Head soot cleaner that BAYER builds.



This is the boiler built by Combustion Engineering Co., bought by the Engineers, Management & Engineering Corp., Chicago, equipped with BAYER soot cleaners and operated by Interstate Power Company, Bemidji, Minnesota.

Another reason why you should buy BAYER. An example of careful engineering all the way through. Let BAYER engineer your next soot cleaner job.

Write for Bulletin No. 63

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